

# **Investigating the Placement of Hopewell Earthworks: A GIS Spatial Analysis of Ross County, Ohio**

## **Honors Research Thesis**

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*with honors research distinction* in Anthropological Sciences  
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## **Abstract**

This honors thesis concerns the placement of the large, often geometric earthworks constructed by the Ohio Hopewell Culture (approximately A.D. 1-400) within the major river valleys of Ross County, Ohio. Least-cost spatial analysis shows that these earthworks are not placed within the closest proximity to the hypothetical easiest routes of travel. Analysis of spatiality, using both Euclidian and Manhattan distances, shows that earthworks were not optimally placed with regard to space. Analysis of environmental factors shows that, while glacial and pre-glacial parent materials and aspect were not chosen for, it does appear that areas with elevations between 639 to 708 feet above sea level, slopes of less than 6 percent, and Eldean loam soils were specifically targeted for the construction of earthworks. While the logic of selecting sites at specific elevations and minimal slope are expected, the selection of Eldean Loam supports a possible explanation that Ohio Hopewell people chose sites that would resist both erosion and the growth of smaller plant life.

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## **Chapter 1: Introduction**

Monuments constructed and abandoned by the people of the past dot the landscape of Southern Ohio. Some of the more impressive ones are the large, geometric, earthworks created during the Middle Woodland period by the Ohio Hopewell Culture. For over two centuries, Ohio inhabitants, as well as outlanders, have taken interest in these earthworks. Research on these earthworks has been almost constant since their discovery by Euroamericans, as have their degradation and, all too often, complete destruction. One interest of Hopewell enthusiasts is the placement of these earthworks, for which multiple explanations are considered plausible. This thesis begins to assess these plausible explanations and builds the groundwork from which a complete, well-supported theory may one day be composed.

The first spatial analysis technique applied, Analysis I, was the least-cost path analysis. The employment of least cost paths was used to test the hypothesis that earthworks were placed along the most easily established routes of travel. The study has implications for the temporal relationships between earthworks. Although some effort has been made to determine the chronology of Ohio Hopewell earthworks based on radiocarbon dating, much is still unknown. The study is useful for examining the correlation between least cost paths and earthwork location in an effort to shed light on or support other theories regarding the sequence of earthwork construction.

The second analysis technique applied, Analysis II, was the spatial patterning analysis. For this analysis the “Average Nearest Neighbor” tool in ArcGIS was utilized and a manual spatial analysis was performed. These processes helped to better understand the spatiality of the earthworks and the patterning of their placement. By determining the patterning of their

placement in regards to space, suggestions of the system by which these earthworks were placed can be made.

The third and final analysis technique applied, Analysis III, was an environmental placement analysis. This analysis looked to explore whether environmental variables could be used to systematically explain where earthworks were placed in the major river valleys of Ross County, Ohio. This analysis included five environmental factors: elevation, slope, aspect, glacial and pre-glacial parent material, and soil type. Examining the placement of nineteen Middle Woodland earthworks in Ross County in comparison to each of these five environmental factors has lent insight into the placement of the earthworks and the relationship the environment may have had to the decision of their placement.

This thesis has established multiple relationships that have shed light on the complex problem of the placement of Ohio Hopewell earthworks in Ross County, Ohio. Analysis I has determined that earthworks do not lie along hypothetical routes of travel, on the contrary, in less accessible locations far from these routes. Analysis II established that spatiality was not taken into consideration in the placement of earthwork, suggesting that earthworks may have been placed in locations for other specific reasons. One possible reason was tested in Analysis III. Analysis III determined that there is a relationship between earthwork placement and several environmental factors, mainly slope, elevation, and soil type, suggesting that these factors may have influenced the placement of earthworks. Together, Analysis I, II, and III have not served to evaluate previously established theories on earthwork placement or even to develop a novel one; rather, they systematically analyzed data in an effort to offer insight and provide an analytical framework onto which future data and analyses can be added, to formulate a well-supported

theory about the placement of the Ohio Hopewell earthworks in the river valleys of Ross County, Ohio.

## Chapter 2: Background on the Hopewell Culture

The river valleys of southern Ohio were areas of much activity during the Woodland Period (1000 B.C. to A.D. 1000). During the Middle Woodland period (A.D. 1 to 400), much of this activity was focused within the region that now comprises modern Ross County. The Ohio Hopewell people are responsible for the construction of these impressive monumental landscapes. This prehistoric Native American culture occupied the Ohio Valley and surrounding region during this time, immediately following the Adena culture of the Early Woodland period. The two cultures are distinguished by archaeologists on the basis of the design of their earthen architectures, burials, and the extensiveness of their interaction sphere. The extent of Hopewell travel is quite extraordinary, spanning to the modern Ontario region of Canada, the Yellowstone region of Idaho and Wyoming, the Gulf of Mexico, and the Blue Ridge Mountains of North Carolina. The use of raw materials from such distances in burial practices begs questions of community organization.

The long standing model of Ohio Hopewell settlement systems was that of the “vacant ceremonial center model”, a variation of the village surrogate model, designed originally by Olaf Prufer (1964a, 1964b, and 1965), later modified by William Dancey and Paul Pacheco (1997), and then critiqued by Wes Bernardini (2004) and Ruby et al. (2005). This model states that earthworks serve as the ceremonial centers of an autonomous polities consisting of clusters of hamlets [see **Figure 1.**] There is not yet enough evidence to empirically evaluate this model for the region and period (Bernardini 2004). The lack of data is due, in part, to Hopewell archaeologists’ original focus on ceremonial centers rather than habitation sites. Recently, the focus has been shifted to include habitation sites, and with time, if there are enough undisturbed habitation sites remaining, sufficient data will be gathered to re-evaluate these models.

The village surrogate model, which was adapted to create the vacant ceremonial center model, was not designed for pre-agricultural North American societies; thus, there are some inconsistencies to be investigated in determining its appropriateness for the Ohio Hopewell. During the Middle Woodland period, the environments of the river valleys of southern Ohio consisted of a mixture of grassy floodplains, woodlands, and rivers, allowing for an easily accessible and abundant subsistence that did not require much effort or travel. An important example of deviation from the village surrogate model is that the Ohio Hopewell did not participate in intensive agriculture and their habitation structures were a modest investment of labor; consequently, they possessed little in the way of value that would need or be worth defending. This lack of fixed investments offers that monuments may lie along lines of movements rather than in the center of the polities (Bernardini 2004:336). The other largest difference between the Ohio Hopewell settlement system and the village surrogate model is the differing functions in morphologically similar earthworks. Functions such as astronomical alignments, which would offer incentive for the Hopewell to travel from one polity to another during the appropriate times of the year to view astronomical phenomenon, are not present at every earthwork (Hively and Horn 1982, 1984, 2006, and 2010).

Ruby et al. (2005) had similar, as well as novel critiques of the vacant ceremonial center model which diminish the likelihood of the model's accuracy. These critiques state that the vacant ceremonial center model fails to incorporate the functional differences of the earthworks of Ross County (Ruby et al 2005:157-159). Squier and Davis (1848) noted the vast differences in function at the beginning of exploration of these earthworks when they classified earthworks in Ohio as either "works of defense" or "sacred enclosures". Recent research has supported their premise of functional differences but failed to corroborate their suggested functions. Research at



hilltop enclosures has determined that they were areas of intensive burning for a plethora of possible reasons (Ruby 1998 and Moorehead 1890), and analyses of the Ginther mound inside of the Cedar-Bank earthworks [5 on **Figure 2**] and the other rectangular platform mounds at the Marietta Earthwork show that these specific earthworks had a particular non-mortuary function, perhaps as a stage for ceremonial processions (Pickard 1996 and Shetrone 1925). Ruby et al. (2005) also asserted that many earthworks were too close in proximity, while the proximity between all earthworks varied too much for the Hopewell inhabitants of the Scioto-Paint Creek Confluence area to have abided by the community settlement pattern demonstrated by the vacant ceremonial system model (Ruby et al. 2005: 159-166). This suggestion was empirically tested using the spatial analysis techniques of nearest-neighbor and Thiessen polygons. Ruby et al. (2005) concluded that the vacant ceremonial center model was incorrect and that Hopewell communities would have used multiple, functionally different earthworks within a general region (Ruby et al 2005:165-167). This conclusion also implies that travel would have been necessary for community members to reach each of the earthworks.

Virtually nothing is known about Hopewell travel because of the lack of evidence it leaves in the archaeological record; however, it is not improbable that Hopewell travel would have differed greatly from that of other historic Native American groups. One aspect of historic Native American trails that is applicable to the Hopewell is their habitual use. The Natchez Trace may be the best example of a trail habitually used as it was beaten ten feet into the ground due to constant use after its construction dating back at least until the Archaic period (8000 – 1000 B.C.) (Davis 1995). Determining the course of trails by Native Americans throughout history has been very variable. Once trails are established they are often used for long durations of time and by later cultures. Such logic applied to the trails that would have been utilized by the Hopewell

people has interesting implications in regards to the Scioto Trail or Warriors' Path, which was a historic Native American trail that ran by the Mound City earthwork [13 on **Figure 2**] (Wilcox 1970:170). The original constructors of this path remain unknown, but it is not unlikely it was the Hopewell people, if not the people who inhabited the region prior to them.

While the anthropological research into Hopewell earthworks has produced a considerable amount of information, much more remains to be done. One potential area of study is the development of monumentality as seen through Woodland period earthworks. The first recorded mounds in Ross County are reported to have been constructed by the Red Ochre Complex in the beginning of the Early Woodland Period (1000 to 0 B.C.), prior to the Adena Culture. These mounds, like those constructed by the Adena Culture except lesser in scale, were conical mounds. The Adena Culture constructed thousands of conical mounds throughout the state of Ohio, forty-six of which were in Ross County (Seeman and Branch 2006:116). The construction of these mounds continued on during the Middle Woodland period, however, simultaneously a new, more complex form of monumentality arose. During this period, the Hopewell Culture began constructing vast, monumental landscapes.

The study of developing complexity and monumentality is certainly not novel. The idea of monumentality and its development has been investigated around the world. The megaliths of North-West Europe (for example: Sherratt 1990), temples of pre-contact Hawaii (for example: Kolb et al 1994), cityscapes and sacred landscapes of Mesoamerica (for example: Joyce 2004), and the mortuary mounds in southern Britain (for example: Barrett 1990) constitute quintessential examples. Literature on monumentality in North America does exist, but the Woodland period is largely underrepresented within it. For a recent example, Burger and Rosenswig devote a section of their book *Early New World Monumentality* to North America,

yet omit in-depth discussion of the Woodland period, only mentioning it in passing in the chapter *Monumentality in Eastern North America during the Mississippian Period* (Burger and Rosenswig 2012).

The chronological theory of earthwork construction garnering the most attention is that earthwork complexity developed over time. There has not been enough research to adequately examine this claim, but existing data are consistent with such an interpretation (Lepper 2005:125). However the progression of earthwork construction arose, it makes for an interesting comparison to the development of social complexity. Even with the recent interest in habitation and other domestic sites, there is not yet enough data to accurately determine the level of cultural complexity during the Middle Woodland Period in Ohio. According to James Brown (1985), cultural complexity in the American Midwest can be identified by the emergence of “permanent habitation, food storage, domestication of plants, multiregional exchange of valuables, cemeteries, intragroup ranking of individuals, and the elaboration of art in a social context.” During the Middle Woodland period, some of these descriptors, such as domestication of plants and multiregional exchange of valuables, are present, and others, such as cemeteries and intragroup ranking of individuals, appear to be absent. The period of use for habitation sites and the elaboration of art in social context have yet to be determined, but when learned, will be telling of the level of social complexity. However, a measure of the social complexity of the Ohio Hopewell relative to cultures long before and long after has limited utility because it will almost certainly find that the social complexity of the Hopewell is intermediate in comparison to those cultures. An accurately constructed chronology of habitation and domestic sites within the Middle Woodland period that has a representative sample of the descriptors listed by Brown (1985) is needed to judge the single-period trend of social complexity.

### Chapter 3: Research of the Hopewell Culture

It is impossible to estimate how much would be known of the Ohio Hopewell earthworks if it were not for some of the early inhabitants of Ross County and their dedication to the mapping and studying of these earthworks. The best known of the early explorers of Ohio Hopewell earthworks are Ephraim G. Squier and Edwin H. Davis, authors of the famed publication *Ancient Monuments of the Mississippi Valley* (1848) [see **Figures 3-18** and **20-24**]. Their book contains maps, with varying degrees of accuracy, of the majority of Ohio Hopewell earthworks, excavation reports of their few excavations, and sketches and reports of the artifacts they unearthed and found most noteworthy (Squier and Davis 1848). This book has been, and continues to be, the starting ground for much research completed on the Hopewell Culture. The work before and proceeding the publication of *Ancient Monuments of the Mississippi Valley* should also be mentioned for the role it has played in Hopewell archaeology. The first known publication including the Hopewell Earthworks of Ross County was *Descriptions of the Antiquities Discovered in the State of Ohio and Other Western States* by Caleb Atwater (1820). This publication is essentially what its title suggests, maps and description of many of the earthworks in Ohio. The quality of these maps is inferior to those of Squier and Davis (1848), as are most of the maps that would follow. Although the work of Squier and Davis (1848) was of good quality for the time, the errors in their work were one of the main focuses of Gerard Fowke's (1902) *Archaeological History of Ohio*. Fowke did offer some new theories on the "Ohio Mound Builders" and similar topics. William Mills (1914) created the most comprehensive set of maps for all earthworks in each of the eighty-eight counties in Ohio, most from the Woodland period, in his *Archaeological Atlas of Ohio* (Mills 1914). Henry C. Shetrone (1922-1925, 1926, 1930) and Warren K. Moorehead (1922) were some of the original, and in

some instances, the only excavators of certain Hopewell earthworks. Both created maps various Hopewell earthworks and these maps are still common reference for present archaeologists. The combination of all aforementioned work by early researchers of the Hopewell culture, as well as many unmentioned, did much in preserving the knowledge of these works before many were destroyed. Although in some instances the work of early researchers was inaccurate, much of the inaccuracy was due, in part, to the condition of the earthworks after many years of farming and human destruction, as well as the technology available at the time. It is thanks to these early researchers that today's research can be performed.

Modern techniques have increased the accuracy of the mapping of known Hopewell earthworks and initiated the discovery of a few new earthworks. The development of remote sensing has been the single most important advancement for accurately mapping Hopewell earthworks. The implementation of remote sensing into the archaeology of Ohio Hopewell earthworks began with aerial photography techniques mastered by Dache Reeves (1936). His photos are still common tools for archaeologists and have been the source for recent discoveries of new Hopewell earthworks (Burks and Cook 2011). Geophysics has been implemented into archaeological contexts to reveal the sometimes non-visible remnants of earthworks by detecting slight variances in physical properties of the soil. Jarrod Burks has discovered much with his application of the magnetometer, ground-penetrating radar, and electrical resistivity meter in surveying Hopewell earthworks (Burks 2006a, 2006b, 2010; Burks and Pederson 2006; Pederson and Burks 2001 and 2002). His advances in documenting these Hopewell earthworks may one day rival the publication *Ancient Monuments of the Mississippi Valley* as the most influential record of Hopewell earthworks (Squier and Davis 1848). Several others (e.g., DeVore 2004, 2005) have also completed geophysical analyses in the region. Light Detection and Ranging

(LiDAR) has also been used by archaeologists to discover and document the remnants of Hopewell earthworks (e.g., Burks and Cook 2011). LiDAR detects the slightest changes in elevation by employing lasers mounted to an aircraft that record elevation at set intervals as the aircraft flies across a landscape. Finally, more advanced techniques for archaeological fieldwork and recent excavations have lent new information about the precise location of Hopewell Earthworks (Brown 2012; Lynott 2009). These archaeological excavations it have determined that it is more accurate to describe earthworks as monumental landscapes, rather than monuments, to reflect their construction and modification over long periods of time (Connolly and Lepper 2004; Lynott 2009; Riordan 1995).

## Chapter 4: Data and Data Acquisition

### I: Analysis of Least Cost Paths

Three essential data sets required gathering or creating for Analysis. First, the digital elevation model (DEM) was downloaded from the Natural Resources Conservation Service of the United States Department of Agriculture's GeoSpatial Data Gateway in the form of multiple tiles. These data were collected at ten meter intervals, per county. These tiles were then mosaiced together to cover the entirety of Ross County. The river data were downloaded in the form of polyline vector data from the portfolio of Patrick Livingwood of Ohio University who repackaged elements of data originally downloaded from the NHDPlus Home website. These data were converted from a vector format into a raster format to be made applicable for the least cost path analysis. The third data set for the study consisted of point data of earthwork location. An original attempt to use the coordinate data provided in appendice 7.1 of *The Scioto Hopewell and Their Neighbors: Bioarchaeological Documentation and Cultural Understanding* (Case and Carr 2008) found that much did not meet desired accuracy. Similarly, some of the data from *Finding Ohio Mounds: A Guide to the Ancient Earthworks of Ohio* (Lute 2012) was inaccurate to varying degrees. To correct these inaccuracies I searched the coordinates provided by both books on Google Earth<sup>TM</sup> and then, based on personal knowledge, the research discussed previously, and the assistance of Dr. Bret Ruby, I verified all earthwork locations. Once verified, these points were added into the GIS. The locational data of some earthworks were not provided in the aforementioned book and these earthworks were located by the author's personal knowledge and verified again by Dr. Ruby. Eighteen of the nineteen sites verified and included in the sample were documented by Squier and Davis in *Ancient Monuments of the Mississippi Valley* (1848): (2) Baum [Plate XXI No. 1, see **Figure 3**]; (3) Blackwater Group [Plate XXII No. 2, see **Figure**

4]; (4) Bourneville Circle [Plate XXX No. 3, see **Figure 5**]; (5) Cedar-Bank [Plate XVIII, see **Figure 6**]; (6) Dunlap [Plate XXIII No. 1, see **Figure 7**]; (7) Frankfort [Plate XXI No. 4, see **Figure 8**]; (8) High Banks [Plate XVI, see **Figure 9**]; (9) Hopeton [Plate XVII, see **Figure 10**]; (10) Hopewell Mound Group [Plate X, see **Figure 11**]; (11) Junction Group [Plate XXII No. 1, see **Figure 12**]; (12) Liberty [Plate XX, see **Figure 13**]; (13) Mound City [Plate XIX, see **Figure 14**]; (14) Seip [Plate XXI No. 2, see **Figure 15**]; (15) Shriver's Circle [Plate XIX, see **Figure 14**]; (16) Spruce Hill [Plate IV, see **Figure 16**]; (18) Trefoil [Plate XXXII No. 5, see **Figure 17**]; and (19) Works East [Plate XXI No.3, see **Figure 18**]. The (17) Steele Group earthwork was not given its own map but was included on the map of the Scioto Valley [Plate II, see **Figure 19**].

The (1) Anderson earthwork was not included in *Ancient Monuments of the Mississippi Valley* and was first mapped by Jerrel Anderson in 1979 [see **Figure 20**]. Four earthworks depicted in *Ancient Monument of the Mississippi Valley* are not included because their precise location is unknown: "Stone Works" [Plate XXX No.4, see **Figure 21**]; "Ancient Works" [Plate XII No.4, see **Figure 22**]; "Hill Works" [Plate XXXII No.3, see **Figure 23**]; and "Works in Chillicothe" [Plate XXXII No.4, see **Figure 24**]. [Numbers inside parentheses coincide with the numbers of **Figure 2**.]

Although every effort was made to retrieve the most accurate data and preserve this accuracy, it is impossible to eliminate all uncertainty from a model. The largest source for uncertainty in the model derives from the river data. The path of any river is constantly changing; therefore, it is unknown how representative the data used is of the rivers two thousand years ago. Another source of uncertainty originates from the interpolation used to create the digital elevation models (DEM). Interpolated data often gives a false sense of accuracy. Elevation data recorded at ten meter intervals is fairly coarse. Furthermore, it is unknown how



much these DEMs have been affected by historic and modern development. The final source of uncertainty exists from the location of earthworks. As aforementioned, the location of earthworks data was verified as much as possible; however, uncertainty still exists with regards to the exact location of some earthworks that have lacked topographic relief for centuries. For example, the Frankfort earthworks were completely demolished with the development of the village of Frankfort, yet there is a seemingly reliable estimate of its location based on the overlaying of historic maps with current ones. Also, as aforementioned, earthworks with unknown locations were not included. Since each earthwork was marked by a point, there was some subjectiveness as to where to locate the point. It was decided that using an informal centroid method would be most appropriate. This method entailed no mathematical determination of the center but rather a visual determination, which only identifies a general location.

## **II: Analysis of Spatiality**

The earthwork data points created for Analysis I were the only data utilized in Analysis II. These earthwork point data was combined into a single file in order to make it compatible with the analysis. This task was completed using the “Merge” tool in ArcGIS 10.1. The uncertainty surrounding earthwork points outlined in the previous paragraph was still applicable to this analysis, with an additional source of uncertainty deriving from the earthworks not included for lack of precise locational data. Due to this analysis’ direct dependence on the location of each earthwork relative to other earthworks, the absence of data for four aforementioned earthworks with unknown locations in this region will skew the results in an immeasurable manner. One of the earthworks not included in this thesis, referred to as “Works in Chillicothe” [Plate XXXII No.3, see **Figure 24**] in *Ancient Monuments of the Mississippi Valley*

(Squier and Davis 1848), was located in downtown Chillicothe which would locate them a few miles east of the Junction Group (11) and Steele Group (17) earthworks causing a large cluster of earthworks in the confluence of Paint Creek and Scioto River in the central portion of Ross County, Ohio [see **Figure 2.**]

### **III: Analysis of Environmental Factors**

Analysis III utilized much new data but reutilized the digital elevation models from Analysis I to calculate aspect. To gather the data elevation, Google Earth <sup>TM</sup> was utilized with its preprogramed elevation data. Aspect is the direction in which a topographic slope faces. The aspect data was gathered from inserting the DEM used in the cost path analyses into the “Aspect” tool in ArcGIS 10.1. The glacial and pre-glacial parent material data was gathered from the *Soil Survey of Ross County, Ohio* (2004). Both the slope and soil type data were collected from the Web Soil Survey produced by the United States Department of Agriculture: National Resources Conservation Service. The Web Soil Survey is a web-based GIS that allows users to choose multiple layers that overlay geographic data (soil type and slope, in the case of this thesis) on a satellite image of the desired area of interest. The layer utilized in this analysis was the “Soil Map” layer utilizing the following versions: survey area: version 14, Dec. 20, 2013, tabular: version 12, Dec. 20, 2013, and spatial: version 5, Dec. 20, 2013. This layer utilized the most recently completed county soil survey for Ross County in the form of a user-interface very similar to Google Maps <sup>TM</sup> that allows the users to pan through the area of interest and zoom in and out while providing multiple tools. It also offers the ability to download the data to be uploaded in another GIS software system. For this thesis, the web-based GIS version was chosen for its simplicity and to eliminate the possibility of improper data projection, which is a common error and source of uncertainty when downloading online data. The data were collected

by panning to the earthwork sites, identifying them on the satellite image, or if needed, comparing the satellite image to an orthophoto overlaid on the GIS created in ArcGIS containing the earthwork locations. Once the earthworks were located, the most dominant soil type was recorded. If two soil types were equally or almost equally dominant at the earthwork site, both were recorded. Looking up the metadata for the symbols depicted for soil type gave additional information including slope and the percentage of the county containing this type of soil.

## **Chapter 5: Methodology: GIS Implementation**

### **I: Analysis of Least Cost Paths**

To determine the path that would have required the least amount of effort for the Hopewell people to travel between earthworks, I used the “cost path” spatial analysis tool in ArcGIS (versions 9.4, 10.0, and 10.1). This tool determines the least effort to move over a terrain. The goal of Analysis I was to determine the path with the least cost, which will be referred to as the ‘least cost path’. The “cost path” tool requires several steps before determining the final path. “Model Builder” in ArcGIS was utilized to create a chain of tools that minimize the time needed to complete the many steps needed to construct a ‘least cost path’.

Data preparation involved creating the cost surface raster (a raster is a set of cells that contain a numeric code representing a spatial phenomenon). A cost surface can contain one or more cost factors. For Analysis I, both slope and rivers were used as cost factors. The more slope a surface has the more difficult it is for a human to travel across. It is also harder for humans to cross rivers as opposed to flatter surfaces with no obstacles. To create the cost raster, the slope had to be calculated. This was completed by inputting the ten meter resolution digital elevation model into the “Slope” tool. The slope must be entered into the “Reclassify” tool to be changed into discrete categories before the GIS is able to run the analysis as using all individual raster cell values would be too burdensome of a computation for most computers. Depending on the amount of classes chosen for the reclassification, the values per class can vary greatly. For Analysis I, thirteen classes were used. They were classified using an equal interval classification scheme which assigns all values into classes that are equal in variance. Each class contained a five percent increase in slope. The final part of the data preparation was conversion of the river

file from vector to raster. To convert, the data was entered into the “Polyline to Raster” tool and the cell size was set to ten in order to be consistent with the digital elevation model.

Once both rasters were created, they had to be prepared for the cost surface. The reclassified slope raster and river raster were entered into the “Weighted Overlay” tool. This tool combined both of the rasters to create a single raster. The “Weighted Overlay” tool allows a user to assign certain weights to each of the data sets inputted, as well as for each of the classes in the data sets. Assigning these weights was one of the more difficult parts of creating the least cost paths. Because these values are arbitrary, it is difficult to make them representative. In the case of Analysis I, it was most difficult to assign the values to the river. Doing so required a determination of what degree of is more difficult to traverse than a river. It was ultimately decided that each of the thirteen classes of slope would receive a value between one and thirteen, while the river received the value of seven. In terms of this model, it means that crossing the river requires as much effort as traveling across land with a thirty to thirty five degree slope. The cost surface raster was then entered into the “cost distance” tool.

The “cost distance” tool estimates the cost of travel over the cost surface from a destination to termination point. After inputting both a single destination point and the cost raster into the “cost distance” tool the output was in the form of two rasters. The first raster contained the direction that incurs the least cost and the second raster contained the accumulation of costs. These two rasters, along with the destination point were the inputs for the final step of using the “cost path” tool. The “cost path” tool uses the two rasters from the cost distance tool as well as the origin point embedded into the rasters to calculate the path of least cost between the destination point and the entered beginning point. For this thesis this gave the path of least effort between any two earthworks (Price 2012) [See **Figure 25**].

## **II: Analysis of Spatiality**

To determine the patterning of spatiality of earthworks in Ross County, Ohio, one spatial statistic tool, the “Average Nearest Neighbor” tool, and the “Measure” tool were used. These tools offered insight into the spatiality of earthworks in this region by assessing the uniformity in distance between each other and the uniformity of clustering or dispersal. This information assisted in determining whether earthwork placement was decided by measurable geographic uniformity.

Analysis II looked to further the spatial analysis completed by Ruby et al. (2005). Their analysis employed the Average Nearest Neighbor analysis to calculate and report the distance between an earthwork and its nearest neighbor. This varies from the goal of this analysis, which stands to determine the ratio of the observed distance divided by the hypothetical random distribution. They also utilized Thiessen Polygons to demonstrate the boundaries of nearest areas to each of the earthworks in Ross County. It is worth noting that they only included fourteen earthworks in their analysis, excluding the Blackwater, Cedar Bank, Junction, Steele, and Trefoil earthworks. Their chapter was published in 2006; since then, the application of geophysics in the region has gathered additional data about the location of unknown earthwork and bettering locating known earthworks. As aforementioned, all earthwork locations were verified by Bret Ruby, who was coauthor of the article cited in this paragraph.

### **IIa: Analysis of Spatiality – Average Nearest Neighbor**

The “Average Nearest Neighbor” tool operates in a simple manner measuring the distance between an earthwork and the next nearest earthwork. This distance (the observed distance) is then divided by the expected distance. The expected distance is the average distance

between a point and the nearest neighboring point in a theoretically random distribution. This analysis returns a Nearest Neighbor Ratio, a Z-score, a P-Value, a Nearest Neighbor Expected Value, and a Nearest Neighbor Observed Value. Only the Nearest Neighbor Ratio, Z-score, and P-Value were utilized in this analysis.

### **IIb: Analysis of Spatiality – Manual Nearest Neighbor**

In addition to Analysis IIa, a similar manual spatial analysis of earthwork distance was utilized for a few reasons. The first reason was to verify the accuracy of the results of the Average Nearest Neighbor analysis. The “Average Nearest Neighbor” tool has two distance capabilities – Euclidean and Manhattan. Euclidean distance is distance by a straight line or as an old idiom states, “as the crow flies”. Manhattan distance is the distance between two points, lines, or polygons on a network. It may be easiest to think about Manhattan distance in terms of travel. If you have to travel from one point in a city to another, it would not be fruitful to utilize a Euclidean distance because your mode of transportation will require that you travel on sidewalks or roads which will obviously not conform to a straight line. The total distance of the sidewalks or roads taken is the Manhattan distance. The Average Nearest Neighbor analysis performed used the Euclidean distance setting because of a lack of network set up to connect each of the earthwork and to judge the spatiality within a larger area disregarding the topography. Thus, one earthwork’s nearest neighbor may be an earthwork that occurs in another river valley, which would be closest according to Euclidean distance but not in terms of the routes likely used to travel, assuming travel occurred within river floodplains. The “Average Nearest Neighbor” tool does not allow a user to check what was determined to be each earthwork’s nearest neighbor which makes a manual analysis fruitful. The second reason this analysis is fruitful is to allow for the separation of different groups of earthworks. Analysis IIb looked at all the earthworks

together, with each neighbor being the next closest earthwork in the floodplain, and also at each of the three separate river valleys – the Paint Creek river valley, the North Fork river valley, and Scioto river valley. Analysis IIb resulted in an average distance, the standard deviation of distance, the median distance, and the first and third quartiles.

### **III: Analysis of Environmental Factors**

Analysis III only used ArcGIS to calculate the aspect values but used a web-based GIS to calculate slope and soil type. To calculate aspect, the DEM downloaded from Natural Resources Conservation Service of the United States Department of Agriculture’s GeoSpatial Data Gateway and originally used in Analysis I was re-utilized as the input field in the “Aspect” tool in ArcGIS 10.1. The only other input field to be filled was the output destination where the users indicate where the file will be saved and under which name it will be saved [see **Figure 26**]. The Web Soil Survey first requires users to choose a state and county as the area of interest. Following the designation of an area of interest, the user is required to look at the layer containing the appropriate data that they wish to utilize. For this analysis, the “Soil Map” layer displayed the appropriate data. It is also worth noting that identical data is displayed in the *Soil Survey of Ross County, Ohio* (2003); however, it is in the form of printed, black and white maps that are less user-friendly and less accurate to use.



## **Chapter 6: Analysis**

### **I: Analysis of Least Cost Paths**

Ideally much information would be gathered from the implementation of least cost path analysis of the Ohio Hopewell earthworks within the Scioto-Paint Creek confluence region, including a temporal sequencing and patterns of earthwork placement based on typological differences, which may reflect differing functions. For Analysis I, the null hypothesis was that there is no relationship between earthwork placement and proximity to the least cost path. The alternative hypothesis is, of course, that there is a relationship between the earthwork placement and proximity to the least cost path, which would then allow for consideration of reasons for the relationship to be explored.

#### **Ia: Analysis of Least Cost Paths – Determining Proximity**

The first least cost-analysis, Analysis Ia, determined whether the Ohio Hopewell earthworks in Ross County were constructed along a path designed to minimize the amount of effort required for travel. More specifically, the purpose of this analysis was to determine if there is a statistically significant correlation between earthwork location and proximity to a least cost path. To accomplish this task, least cost paths were employed using the “Best\_Single” setting for path type. This setting allowed the path to have the lowest cumulative cost in lieu of the “Each\_Cell” setting, which determines the path by selecting each successive cell by the lowest cost available without regard to the total cost. Multiple least cost paths were created in an effort to develop paths most representative of those taken by the Hopewell. There is no reason to assume that travel from earthwork to earthwork strayed far from the river banks and surrounding grass floodplains, as they provide the greatest abundance of resources needed for subsistence, as well as a terrain with relatively little slope to endure. All known earthworks and habitation sites

are located within a close proximity to a river. Running a single path between all earthworks would encourage the least cost path to deviate an unrealistic distance from the river. Therefore, three paths were run. The first path is the Paint Creek Path, which consists of the (18) Trefoil, (14) Seip, (2) Baum, (16) Spruce Hill, and (4) Bourneville Circle, earthworks in the respective order [see **Figure 2.**] The second path is the North Fork path, which consists of the (7) Frankfort, (10) Hopewell Mound Group, (1) Anderson, (17) Steele, and (11) Junction Group earthworks in the respective order [see **Figure 2.**] The final path is the Scioto Path, which consists of the (3) Blackwater Group, (6) Dunlap, (5) Cedar-Bank, (9) Hopeton, (13) Mound City, (15) Shriver's Circle, (19) Works East, (8) High Banks, and (12) Liberty earthworks in the respective order [see **Figure 2.**] To determine whether or not the relationship between earthwork placement and proximity to the least cost path is significant, both the distance from each earthwork to the river and the earthwork to the respective least cost path was calculated using the "Measure" tool in ArcGIS. The proportion of earthworks that have a closer proximity to the least cost path rather than the river was used as the  $\hat{p}$ , while the proportions of earthworks that have a closer proximity to the river rather than the cost path was used as the  $p_0$ . Given these two statistics, a standard significance test for proportions was used to determine whether or not the relationship between earthwork placement and proximity to the least cost path is statistically significant. This test of significance was first used to determine whether all least cost paths were statically significant. Then the significance test determined if each individual least cost path were statistically significant [See **Figure 4**].

### **Ib: Analysis of Least Cost Paths – Determining Chronology**

The second least-cost analysis, Analysis Ib, had the goal to build a seriation of many of the Ohio Hopewell earthworks in Ross County. To temporally situate each earthwork, the

methods used were much the same as described in Analysis Ia except on a smaller scale. In order to complete this analysis, it was necessary to compare with a previously established model. The model best suited for this thesis is a theory published multiple times by Warren DeBoer and is the current general consensus of many archaeologists (DeBoer 1997 and DeBoer 2010:186-193). This model asserts that complexity in earthwork architecture developed over time. Therefore, it is derived that the small circular or non-geometric earthworks were the first to be constructed. Following these smaller earthworks would have been the medium-sized geometric earthworks and finally the larger, complex, and often times tripartite earthworks. This model does not currently have the empirical data to support it due to the lack of chronometric dates from the smaller and medium size earthworks; however, the radiocarbon dates for the larger, more complex earthworks do fall within the later portion of the Middle Woodland Period (Lepper 2005:125).

The implementation of least cost paths to deduce the desired information required creating many paths of shorter distances. The premise used was that creating a least cost path from one perceived older earthwork to another perceived older earthwork would create a path that runs within a close proximity to a perceived younger earthwork. It can be assumed that if earthworks were being constructed in close proximity to paths of travel, that new earthworks would be intentionally constructed within a close proximity to the path connecting two pre-existing earthworks on either side of the newer earthwork. Empirically testing this assumption is only useful because the previous analysis did not return a high level of statistical significance. If it had, the smaller paths created for this analysis would overlap the three paths created for the previous analysis. It is also evident that this will not work for all the earthworks because not all of the perceived younger earthworks are surrounded by perceived older earthworks. The

Frankfort (7), High Banks (8) Hopewell Mound Group (10), and Liberty (12) earthworks are all perceived younger earthworks but are at the farthest extent of their respective paths. This method was applicable to determine if the Cedar-Bank (5), Dunlap (6) Hopeton (9), and Mound City (13) earthworks lie within a close proximity to a path created between the Shriver's Circle (15) and Blackwater Group (3) earthworks. It was also applicable to determine if the Seip (14) and Baum (2) earthworks lie within a close proximity to a path created between the Trefoil earthworks (18) and Spruce Hill earthworks (16), and if the Dunlap (6) earthwork lies within a close proximity to a path created between the Anderson (1) and Cedar-Bank (5) earthworks. The same statistical test as in the previous analysis was used to determine if the relationship between these earthworks and the proximity to the least cost path is statistically significant.

#### **Ic: Analysis of Least Cost Paths – Comparing Typology and Proximity**

The final least-cost analysis, Analysis Ic, planned to be performed, had the goal of determining whether or not typological differences in earthwork architecture correlates with the distance the earthworks lie from the least cost path. This analysis would have reused the Paint Creek, North Fork, and Scioto paths created in the first analysis; therefore, since the first analysis failed to result in a significant relationship between earthwork placement and proximity to the least cost path, this analysis could not be completed. For the sake of Analysis Ic, each of nineteen earthworks in Ross County was placed into one of four informal groups. The first is the “weird” group and was constructed on the basis of the uniqueness in typology that is either quite rare or never observed again in Hopewell earthworks. This group consists of the Anderson (1) Blackwater Group (3), Junction Group (11), Mound City (13) and Trefoil (18) earthworks. The second is the “tripartite” group which was constructed on a basis of having a tripartite typology of one large circle, one small circle, and one square. This group consists of the Baum (2),

Frankfort (7) Liberty (12), Seip (14), and Works East (19) earthworks. The third is the “geometric group” which was categorized on a basis of having roughly a geometric typology. This group consists of the Bourneville Circle (4), Cedar-Bank (5), Dunlap (6), High Banks (8), Hopeton (9), Hopewell Mound Group (10), Mound City (13), and Shriver’s Circle (15) earthworks. The fourth group is “hilltop enclosures” and was categorized on the basis of the earthwork being a large enclosure lining the top of a flattened hilltop. The only earthwork within Ross County that is considered a hilltop enclosure is the Spruce Hill earthwork (16).

The distance from each earthwork to the least cost path would have been reused from the first analysis and the mean distance to the least cost path would have been calculated for each typological group (the distance from the earthworks that were used as endpoints would not have been included in this calculation because their values would be zero). The mean distance would have been calculated for all nineteen earthworks. For each typological group, it would have been determined whether more members of the group were farther or closer to the least cost path relative to the mean value. Once this was determined, the proportion of the group that was either farther or closer depending on what was decided in the previous step would have been used as  $\hat{p}$ . The same determination of either farther or closer would have been used to calculate the proportion of the total number of earthworks that are the same proximity (either farther or closer) as decided on for the sample proportion and would have been used as the  $p_0$ . For example, if the group consisted of three out of four earthworks being closer to the least cost path than the mean (statistically demonstrated by having a distance less than the mean value) and only six of the nineteen total earthworks were closer, the  $\hat{p}$  would be 0.75 and the  $p_0$  would be 0.3158. Given these two statistics, a standard one sided significance test (based on whether the group is considered nearer or farther than the mean distance) for proportions would have determined

whether or not the relationship between earthwork placement per typological group and proximity to the least cost path was statistically significant. If significance is detected, the procedures would have been repeated with a slight modification of the  $P_0$  calculation. Instead of using the proportion of the total that are either closer or farther, the new value would have been the proportion of the group that was either closer or farther, with the next closest mean distance to the least cost path. This exact same procedure may have needed to be repeated depending on whether the three groups were closer or farther away from the mean. Had this significance test been able to be completed, it would have determined how many of the groups have a unique and significant relationship between earthwork placement and proximity to the least cost path.

## **II: Analysis of Spatiality**

Analysis II sought to gather much information regarding the spatiality of earthworks in the river valleys of Ross County, Ohio. For this analysis, the null hypothesis was that there is no spatial patterning among earthworks or, in other words, the earthworks are randomly placed. There were two alternative hypotheses; the first was that the earthworks are dispersed and the second was that the earthworks are clustered. Although failing to reject the null hypothesis does not offer an explanation that the Hopewell people were spatially minded when deciding the location of earthworks, either one of the alternatives does.

### **IIa: Analysis of Spatiality – Average Nearest Neighbor**

Analysis IIa utilized the “Average Nearest Neighbor” tool in ArcMap 10.1. This tool has a simple setup user interface with few inputs [see **Figure 27**]. The only manipulated field in this setup user interface was the “Input Feature Class” field which was filled with the “Earthworks\_Merge” shapefile which contained all nineteen of the earthworks in their

geographic positions within Ross County, Ohio. The “Distance Method” field was kept the same (“Euclidean Distance”) because the earthwork points are not connected on a network, which would be required for using the other distance method – Manhattan distance. The “Generate Report (optional)” box was checked, which simply gave a graphical representation of the results in an html format following the successful completion of the analysis [see **Figure 28**]. The “Area (optional)” field was left empty. This field sets the study area. When the field is left empty, the default setting is a rectangle that encloses all the points, lines, or polygons in the inputted shapefile – which was appropriate for this analysis. This analysis returned a Nearest Neighbor Ratio, a Z-score, a P-Value, a Nearest Neighbor Expected Value, and a Nearest Neighbor Observed Value, of which the Nearest Neighbor Ratio, Z-score, and P-value were further analyzed. The data points were also plotted to examine their distribution.

### **IIb: Analysis of Spatiality – Manual Nearest Neighbor**

Analysis IIb performed similar procedures as Analysis IIa but manually. First, the “Measure” tool was utilized to determine the distance between one earthwork and the neighboring earthwork in the same river valley, with the one exception being the Spruce Hill earthwork (16), which is technically out of the river valley but was measured in the same manner. The measurements connect at the confluence of all three rivers. The measurements were taken in the following order starting in the Paint Creek valley with the (18) Trefoil earthworks to (14) Seip earthworks to (2) Baum earthworks to (16) Spruce Hill earthworks to (4) Bourneville Circle earthworks to (11) Junction Group earthworks and connected to the Scioto River valley at (19) Works East earthworks. The North Fork valley went as followed: (7) Frankfort earthworks to (10) Hopewell Mound Group earthworks to (1) Anderson earthworks to (17) Steele Group earthwork and connected to the Paint Creek valley at (11) Junction Group earthwork. The Scioto

River Valley went as follows: the (12) Liberty earthwork to the (8) High Banks earthwork to the (19) Works East earthwork to the (15) Shriver's Circle earthworks to the (13) Mound City earthworks to the (9) Hopeton earthwork to the (5) Cedar Bank earthworks to the (6) Dunlap earthworks and finished at the (3) Blackwater earthworks. Once these measurements were compiled, an average distance was calculated, as well as the standard deviation, median and first and third quartiles. The data points were also plotted to examine the distribution

### **III: Analysis of Environmental Factors**

Analysis I and II examined the relationship of earthwork placement and possible paths of travel and general spatiality; Analysis III sought to offer insight to the relationship of earthwork placement and environmental factors including elevation, slope, aspect, glacial and pre-glacial parent material, and soil type. The first environmental factor examined was elevation. The elevation data was collected by going to each of the points plotted in Google Earth™ for the data gathering needed in Analysis I, panning over the point, reading the elevation, and recording it. Following the data collection, the elevation data was averaged and the standard deviation was calculated. The data points were also plotted to examine the distribution.

The second environmental factor examined was slope. The slope data was included in the soil type data collected from the "Web Soil Survey" produced by the Natural Resources Conservation Service of the United States Department of Agriculture. Once the data were collected, no further analysis was needed – the results were obvious.

The third environmental factor examined was aspect. The aspect data was created from a DEM in ArcGIS. Once the aspect raster was created, determining the aspect at each earthwork



site required zooming in to the data pixel containing each earthwork and recording the aspect data. Once the data were collected, the percentage of each aspect represented was calculated.

The fourth environmental factor examined was glacial and pre-glacial parent material. This data was collected from the *Soil Survey of Ross County, Ohio* (2003). After the data was collected, no further analysis needed to be completed – the results were obvious.

The fifth and final environmental factor examined was soil type. Following the collection of the data, percentages were calculated for each type of the soils represented. Also, data was collected for the percentage of the entire county that each soil type represented at earthwork sites. This data was compared with the percentage of each soil type represented at earthwork sites.

## Chapter 7: Results

### I: Analysis of Least Cost Paths

#### Ia: Analysis of Least Cost Paths – Determining Proximity

The results from the first least-cost analysis, Analysis Ia, determined that the distance between the earthworks and the least cost paths are not statistically significant [see **Figure 29**]. Each of the distances from each earthwork to both the closest river and least cost path are listed on **Figure 30**. The pre-set Table A standard normal cumulative proportion needed to classify the relationship between a least cost path and earthworks as statistically significant was 0.9000, which all least cost paths failed to meet. The  $\hat{p}$  for the (1) Anderson, (2) Baum, (5) Cedar-Bank, (6) Dunlap, (8) High Banks, (9) Hopeton, (10) Hopewell Mound Group, (13) Mound City, (14) Seip, (15) Shriver's Circle, (16) Spruce Hill, (17) Steel Group, and (19) Works East earthworks and their respective least cost paths is 0.38 and the  $p_0$  is 0.62. The z-score is -1.78, which corresponds with a Table A standard normal cumulative proportion of 0.0375. The  $\hat{p}$  for the (2) Baum, (14) Seip, and (16) Spruce Hill earthworks and the Paint Creek least cost path is 0.33 and the  $p_0$  is 0.67. The z-score is -1.25, which corresponds with a Table A standard normal cumulative proportion of 0.1056. The  $\hat{p}$  for the (1) Anderson, (10) Hopewell Mound Group, and (17) Steele Group earthworks and the North Fork least cost path is 0.33 and the  $p_0$  is 0.67. The z-score is -1.25, which corresponds with a Table A standard normal cumulative proportion of 0.1056. The  $\hat{p}$  for the (5) Cedar-Bank, (6) Dunlap, (8) High Banks, (9) Hopeton, (13) Mound City, (15) Shriver's Circle, and (19) Works East and the Scioto least cost path is 0.43 and the  $p_0$  is 0.57. The z-score is -0.7481, which corresponds with a Table A standard normal cumulative proportion of 0.2266.

### **Ib: Analysis of Least Cost Paths – Determining Chronology**

The results from the second least-cost analysis, Analysis Ib, like the first, determined that the distance between earthworks and the least cost path are not statistically significant and cannot be used in temporally situating the earthworks of Ross County [see **Figure 31**]. Each of the distances from each earthwork to both the closest river and least cost path are listed on **Figure 32**. Path 1 was intended to support the hypothesis that the (5) Cedar-Bank, (6) Dunlap, (9) Hopeton, and (13) Mound City earthworks were constructed more recently than the (3) Blackwater and (15) Shriver's Circle earthworks by establishing a statistically significant correlation between the path created between the (3) Blackwater and (15) Shriver's Circle earthworks and the hypothesized younger earthworks. The  $\hat{p}$  for these earthworks and Path 1 is 0.25 and the  $P_0$  was 0.75. The z-score is -2.31, which corresponds with a Table A standard normal cumulative proportion of 0.0104. Path 2 was intended to support the hypothesis that the (2) Baum and (3) Seip earthworks were constructed more recently than the (18) Trefoil and (16) Spruce Hill earthworks by establishing a statistically significant correlation between the path created between the (18) Trefoil and (16) Spruce Hill earthworks and the hypothesized younger earthworks. The  $\hat{p}$  for these earthworks and Path 2 is 0.50 and the  $P_0$  was 0.50. The z-score is 0.00, which corresponds with a Table A standard normal cumulative proportion of 0.5000. Path 3 was intended to support the hypothesis that the (6) Dunlap earthwork was constructed more recently than the (3) Blackwater and (5) Cedar-Bank earthworks by establishing a statistically significant correlation between the path created between the (3) Blackwater and (5) Cedar-Bank earthworks and the hypothesized younger earthworks. The  $\hat{p}$  for these earthworks and Path 1 is 0.00 and the  $P_0$  was 1.00. The z-score is -1.00, which corresponds with a Table A standard normal cumulative proportion of 0.1587.

### **Ic: Analysis of Least Cost Paths – Comparing Typology and Proximity**

The third least-cost analysis, Analysis Ic, aimed to determine if there is a correlation between how far an earthwork is from the least cost path and architectural design. Unfortunately, this analysis could not be completed because it was reliant on Analysis Ia determining the distance from earthworks to the least cost paths was statistically significant.

## **II: Analysis of Spatiality**

### **Ila: Analysis of Spatiality: Average Nearest Neighbor**

Analysis Ila results came in the form of 3 telling statistics – the Nearest Neighbor Ratio, the Nearest Neighbor Z-score, and P-value [see **Figure 33**] The results fail to reject the null hypothesis that there is no spatial pattern among the earthworks and do not indicate that general spatiality was taken into consideration when placing the earthworks. The Nearest Neighbor ratio of 1.007052 indicates that the earthworks tend toward being dispersed rather than clustered; yet, the ratio states that the earthworks are clearly random. Randomness indicates that the earthworks were placed in a manner where in some locations they are dispersed while in other locations they are clustered. The Nearest Neighbor Z-score of 0.058809 indicates that the results do not significantly deviate from normal (random). The P-Value of 0.953105 adds confidence to the decision to fail to reject the null hypothesis.

### **Ilb: Analysis of Spatiality – Manual Nearest Neighbor**

Analysis Ilb performed a linear Nearest Neighbor analysis that looked to investigate the pattern of spatiality of earthwork only considering their position in the river valleys. The distances from each earthwork to its neighbor within the river valley were recorded in **Figure 34**.

Considering all the earthworks at once, on a single network within the river valleys, did not provide insightful results. The average distance was 4.804724 kilometers while the standard deviation was 2.973963 kilometers. Under both a standard deviation and equal interval classification scheme, the distribution of the distances to nearest neighbor was unimodal and close to normal with a slight skew to the right [see **Figures 35** and **36**]. The median distance was 4.5694825 kilometers, while the inter-quartile range was 2.38521925 to 6.42881975 kilometers. 68.4 percent of distances fall within one standard deviation of the mean, 89.4 percent of distances fall between two standard deviations, and 94.7 percent of distances fall within three standard deviations – further demonstrating how close to normal the distance are.

Due to results of the initial manual linear nearest neighbor analysis which determined a lack of patterning of earthwork placement, an extra effort was made to determine if investigating spatiality could make sense of earthwork placement. To further the previous analysis, the earthworks were separated into three neighborhoods, following the same separation schemes as Analysis Ib (Paint Creek, North Fork, and Scioto Valleys). The distance from each earthwork to its nearest neighbor was recorded in **Figure 37**, as well as the average distance and standard deviation. In the Paint Creek Valley the average distance was 4.695964 kilometers and the standard deviation was 1.620366 kilometers. In the North Fork Valley, the average distance was 4.696656 kilometers and the standard deviation was 3.285128 kilometers. In the Scioto valley the average distance was 3.673160 kilometers and the standard deviation was 2.363767 kilometers. These results do not offer much more insight as the standard deviations, with the exception of the Paint Creek Valley, are over half the value of the average. It is worth noting that the earthworks in the Paint Creek Valley are more evenly spaced than the other two valleys and their patterning is evident in a visual examination of their locations on a map [see **Figure 2**].

### III: Analysis of Environmental Factors

An investigation of environmental factors and earthwork sites has determined that there is a relationship between certain environmental factors and earthwork placement [see **Figure 38** for all recorded data for Analysis III]. The first environmental factor was elevation, which showed a strong relationship between elevation and earthwork placement. The maximum elevation in Ross County, Ohio is 1,342 feet while the minimum is 559 feet (Hamilton and Lucht 2003). The earthwork with the highest elevation was the Spruce Hill earthwork which was 1047 feet above sea level and also an outlier to this data set. However, since the Spruce Hill earthwork was the only hilltop enclosure ever recorded in Ross County, this is not surprising. Disregarding the Spruce Hill earthworks, the Trefoil earthwork has the next highest elevation at 750 feet. The Works East earthwork has the lowest elevation at 604 feet. The average elevation of earthworks including the outlier was 692.58 feet and the standard deviation was 95.11 feet. Excluding the outlier, the average height was 672.89 feet and the standard deviation was 42.18 feet [see **Figure 39**]. In future references to this dataset throughout this thesis, the elevation data utilized will exclude the outlier. The distribution of earthwork elevations were plotted in two different fashions, one with bins based on an equal interval classification scheme and another with classes based on a standard deviation classification scheme. Both histograms show a distribution that has a slight skew to the right; however, the equal interval histogram is bimodal and the standard deviation histogram is unimodal [see **Figures 40 and 41**]. The median elevation was 677.5 feet, with an interquartile range from 639 feet to 708 feet. 68.4 percent of all elevations fall within one standard deviation of the mean, 94.7 percent fall within two standard deviations with the one remaining datum being an outlier.

The slope data gathered for Analysis III did not offer much insight into possible explanations of earthwork placement. All of the earthworks were constructed in areas with slope no greater than six percent, with the vast majority having slopes of zero to two percent. Without the modern complex instruments and methods able to record elevation, people of the Hopewell culture would not have been able to detect such minute variations of the slope.

Similarly to the slope data gathered, the aspect data offer little insight into earthwork placement. There seems to be no detectable trends in relation to aspect and earthwork placement and the map of aspect in the county is highly variable due to the small rounded foothills of the Appalachian Mountains present in the region [see **Figure 42**]. The most dominant aspect was east, with 21.05 percent of earthworks in the category, followed by southeast and south west with 15.79 percent, flat or no aspect, northeast, and west with 10.53 percent, and lastly north, south, and northwest with 5/26 percent [see **Figures 43 and 44**]. Due to the little variation in slope at the sites of earthworks, it would have been difficult to detect aspect two thousand years ago. Thus, following the result of the analysis of slope at earthwork sites, the lack of utility of the results for aspect is unsurprising.

The analysis of glacial and pre-glacial parent materials showed a strong correlation with earthwork placement, yet, does not offer much insight into the possible explanation of placement choices. All of the earthworks appear to have been constructed on Wisconsin age terraces. However, the entirety of the Scioto River and Paint Creek floodplains consists of Wisconsin terraces. Thus, since all the earthworks are placed within such close proximity to these bodies of water, it seems as if the correlation is a fallacy rather than a meaningful relationship.

Likely the most telling environmental factor was the soil type. There were six different soil types present at earthwork sites – Eldean Loam, Eldean Gravelly Loam, Miamian Silt Loam, Mentor Silt Loam with Gravelly Substratum, Gessie Silt Loam, and Rossmoyne Silt Loam. 56.52 percent of earthwork sites were completely or partially composed of Eldean Loam, while 26.09 percent were composed of an Eldean Gravelly Loam which has the same soil composition as the Eldean Loam only with a higher prevalence of gravel. Altogether, soil with an Eldean Loam composition was present at 82.61 percent and fifteen of the nineteen earthworks. The four other soil types: Miamian Silt Loam, Mentor Silt Loam with a Gravelly Substratum, Gessie Silt Loam, and Rossmoyne Silt Loam, were found at only one earthwork site [see **Figures 45 and 46**]. The high prevalence of Eldean Loam at earthwork sites is surprising. Of all the soil in Ross County, Ohio, only 3.4 percent of it is comprised of an Eldean Loam. Also, only 0.7 percent of the soil in Ross County is an Eldean Gravelly Loam. Combined, that is 4.1 percent, or 18,183.91 of the 443,510 acres of the soil in Ross County are either an Eldean Loam or Eldean Gravelly Loam.

Due to the high correlation of earthwork placement and soil type, it was decided that further analysis should be done in order to determine if this relationship was a fallacy. Knowing that this soil type occurs at a very low frequency over the entirety of the study area, the way in which this relationship may be a fallacy is if this Eldean Loam soil type is mostly present at certain landforms upon which the earthworks were constructed. To test for this a chi-square statistical analysis was performed between elevation and soil type at earthworks sites. If Eldean Loam soils were only present upon certain landforms upon which earthworks were constructed it would be expected that there would be a strong correlation between elevation and soil type. For this statistical analysis, the null hypothesis was that there was no relationship between elevation and soil type while the alternative hypothesis was that there is a relationship. A simple three by



two contingency table was constructed. The three columns consisted of three classes of elevation broken on an equal interval classification scheme excluding the one outlier. However, this outlier was included in the third class. The two rows consisted of Eldean Loam soils and non-Eldean Loam soils. Both Eldean Loam and Eldean Gravelly Loams were included in the Eldean loam categories. After the contingency table was completed, the expected values were calculated and finally the contribution of each cell was calculated. Totaling the contributions gave the chi-square statistic which was compared to the Table-D value to determine statistical significance.

The resulting statistics fail to reject the null hypothesis and do not offer support for the alternative hypothesis. The contingency table, the table of expected and observed values and the table of contributions can be found in **Figures 47, 48, and 49** respectively. The chi-square value was 0.4956, which is less than 5.99, the needed value according to Table-D to reject the null hypothesis. This Table-D value was chosen with two degrees of freedom and an upper tail probability of 0.05. The chi-square test has offered no support for a relationship between elevation and soil type.

## **Chapter 8: Conclusions**

### **I: Analysis of Least Cost Paths**

The statistical analysis of the distance of earthworks from least cost paths fails to reject the null hypothesis that there is no relationship between earthwork placement and proximity to the least cost path and offers no support for an alternative hypothesis. That being said, this experiment does not conclude or even support, that Ohio Hopewell earthworks did not lie along common routes of travel. The possibility that data uncertainty accounted for the failure to establish statistical significance is certainly present. As the least cost paths were being created, it was noticed that they often coincided with the modern roadways of Ross County. The development of the floodplains of the Scioto River and its tributaries has created a terrain that likely lacks many of the features present two thousand years ago. This altered terrain can drastically affect the route taken by a least cost path, and subsequently affect the accuracy of the analysis. Ultimately, the terrain that existed two thousand years ago cannot be recreated, and the utilization of the most accurate models of the present terrain in the creation of least cost paths fail to result in statistically significant correlation between the placement of earthworks and the least cost paths. The resulting extreme statistical insignificance may also offer support to alternative interpretations. It may support that the Hopewell people chose against the locations tested for in Analysis I - area of easy access from common routes of travel. Instead of these areas, they may have selected areas that were more difficult to arrive at. It has been suggested by some that both Newark, Ohio and Chillicothe, Ohio were pilgrimage destinations for the Hopewell that were connected by roads and people from a diverse group of places (Lepper 2006: 122-133). Considering the Hopewell earthworks of Ross County, Ohio as pilgrimage sites and comparing them to other sites that have been interpreted (although sometimes controversially) as

pilgrimage centers such as Monte Alban (Augur 1954: 103) and Machu Picchu (Magli 2009) whose locations are, in no way, easily accessible, it may come as no surprise that these earthworks are not located in the easy locations to arrive at.

## **II: Analysis of Spatiality**

The investigation of spatial patterning in Analysis IIa and IIb did not result in support of a theory that the Hopewell people determined locations of earthwork construction on general spaciality within Ross County, Ohio. Utilizing the “Average Nearest Neighbor” tool and completing a manual evaluation of network spatial patterning gave results that show the placement of earthworks with regard to space is random or without pattern. This result may have been affected by the four earthworks whose exact locations are unknown and were not included in this thesis. Also, this result could support a theory that the Hopewell disregarded general spaciality in order to select locations for a specific reason, such as for the environmental factors present.

## **III: Analysis of Environmental Factors**

An investigation of environmental factors at earthwork locations has provided insight into the placement of the nineteen earthworks on the floodplains of the major river valleys in Ross County. The examination of aspect and glacial and pre-glacial parent material offered little insight into the placement of earthworks. However, the examination of elevation, slope, and soil types has offered insight. The examination of elevation at earthwork sites has shown that the sites tend to fall within an elevation of 639 to 708 feet, a range of only 69 feet within a county that has a total range of 783 feet. Similarly, all earthworks were built in areas that contained slope of 6 percent or less. Finally, it has been demonstrated that a preference for Eldean Loam and Eldean Gravelly Loam soil types was present. There are two possible explanations that can

either stand alone or work together to explain why earthworks were constructed mainly in areas containing Eldean Loams. The first is that Eldean loams are resistant to erosion – they are well drained, do not flood or pond, have a deep depth to seasonal high water table, and only have a slight hazard of wind erosion (Hamilton and Lucht 2003). The second reasoning is that Eldean loams do not offer good support for small plant life – the high clay content can restrict rooting depths and the soil has a low capacity to hold and retain moisture needed to sustain plants that have fibrous root systems or short taproots (Hamilton and Lucht 2003). The usefulness of sites and soils with little erosion in earthwork construction is obvious, but lack of the ability to support smaller plant life is deserving of elaboration. The implementation of modern farming equipment and practices has turned the sites of these earthworks into both cropland and pastureland; however, these sites, once deforested, likely would have been easier to keep free of smaller vegetation. Although the appearance of earthwork sites in regard to their vegetation at the time of use is a discussed topic among Hopewell archaeologist, there is no evidence as to how these sites were maintained. Mark Lynott recently collected phytolith samples from multiple stratigraphic layers at Mound City in an effort to reconstruct how these sites may have been maintained but the results have yet to reach publication (Information Gained Through Personal Communication with Mark Lynott and Participation in Excavations at Mound City in the Summer of 2012). If the Hopewell people did desire to keep these sites free of smaller vegetation such as saplings, shrubs, and bushes, Eldean loams would have provided an ideal soil type. These findings offer support to a theory that the Hopewell people were mindful of many environmental factors when choosing locations to construct their earthworks.

The chi-square statistic determined that there was no statistical significance between elevation and soil type, supporting that the high correlation between the Eldean Loam soil type

and earthwork placement are not caused by an ecological fallacy. Had this relationship been statistically significant it would have supported that the correlation between earthwork placement and soil type was likely due to the soil type present at the land forms upon which earthworks were constructed. However, the chi-square was highly insignificant adding confidence to the interpretation that the Hopewell people chose earthwork sites with cognizance of the soil type present.

### **I, II, and III**

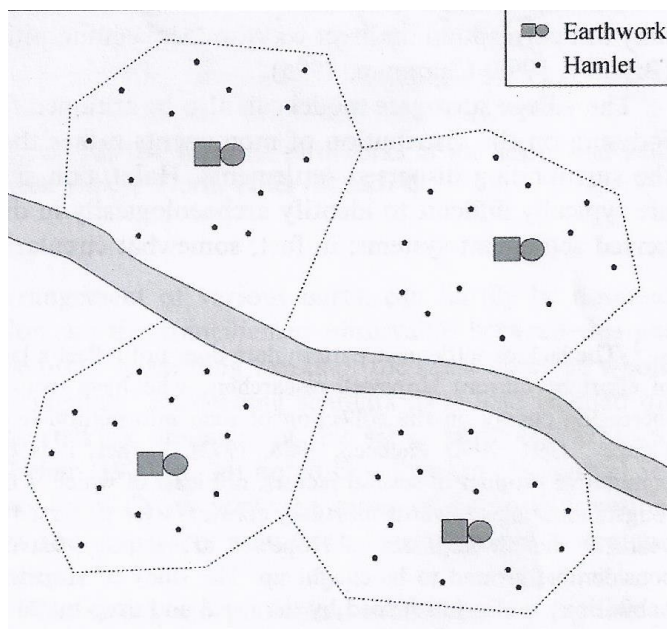
This thesis has applied many spatial analysis techniques in order to gather insight into the placement of the Ohio Hopewell earthworks within Ross County, Ohio by investigation their relationship to possible routes of travel, to space, and to the environment. Although not all of the analyses resulted in positive, statistically tested relationships between these elements and earthworks, this thesis stands as a good platform in which to build further research of the earthworks. It has offered a novel manner in which to utilize least-cost path analyses to deduce desired information. This thesis has built upon the study of Ohio Hopewell earthwork spatiality began by Ruby et al. (2005) and it hopes to offer ideas to reuse and further by future researchers. Finally, it has offered an evaluation of the relationship between the environment and these built Hopewell monumental landscapes. Altogether, even though the research did not offer a novel theory, it has taken the first step toward understanding the placement of earthworks in the major river valleys of Ross County, Ohio.

## Chapter 9: Final Thoughts

As is often the case with research projects, this thesis has brought about many other questions that are deserving of future research. Although the utility of least-cost paths to answer the specific question of the thesis is limited, their utilization within other research into the Ohio Hopewell Culture are many. There remains many ways in which to further the study of Spatiality of earthworks in Ross County. One of the most telling methods may be to build a regression model to analyze the presence of earthworks within a grid overlaid on the entirety of Ross County, Ohio. It is also understood that this thesis examined a very limited number of environmental factors. Analysis III could be easily expanded on to make it a more thorough examination of the relationship of environment and earthworks. Ultimately, more data needs to be collected archaeologically. Temporally sequencing the earthwork may be one manner in which insight into the placement of earthwork may be gained. Knowing the progression of their construction across the county could allow for better understanding the reasons they now resided in the specific locations that they do. Similarly, gathering more data to examine their uses could be helpful in understanding the decisions being made in their placement. The list of enlightening archaeological research would be extensive, yet there remains more that can be done non-destructively to understand the phenomenon that is the placement of Ohio Hopewell earthworks in Ross County, Ohio.

## Figures

**Figure 1.**



**Figure 1.** Illustration of the vacant ceremonial model (taken from Bernardini 2004, which was redrawn from Dancey and Pacheco 1997)

Figure 2.

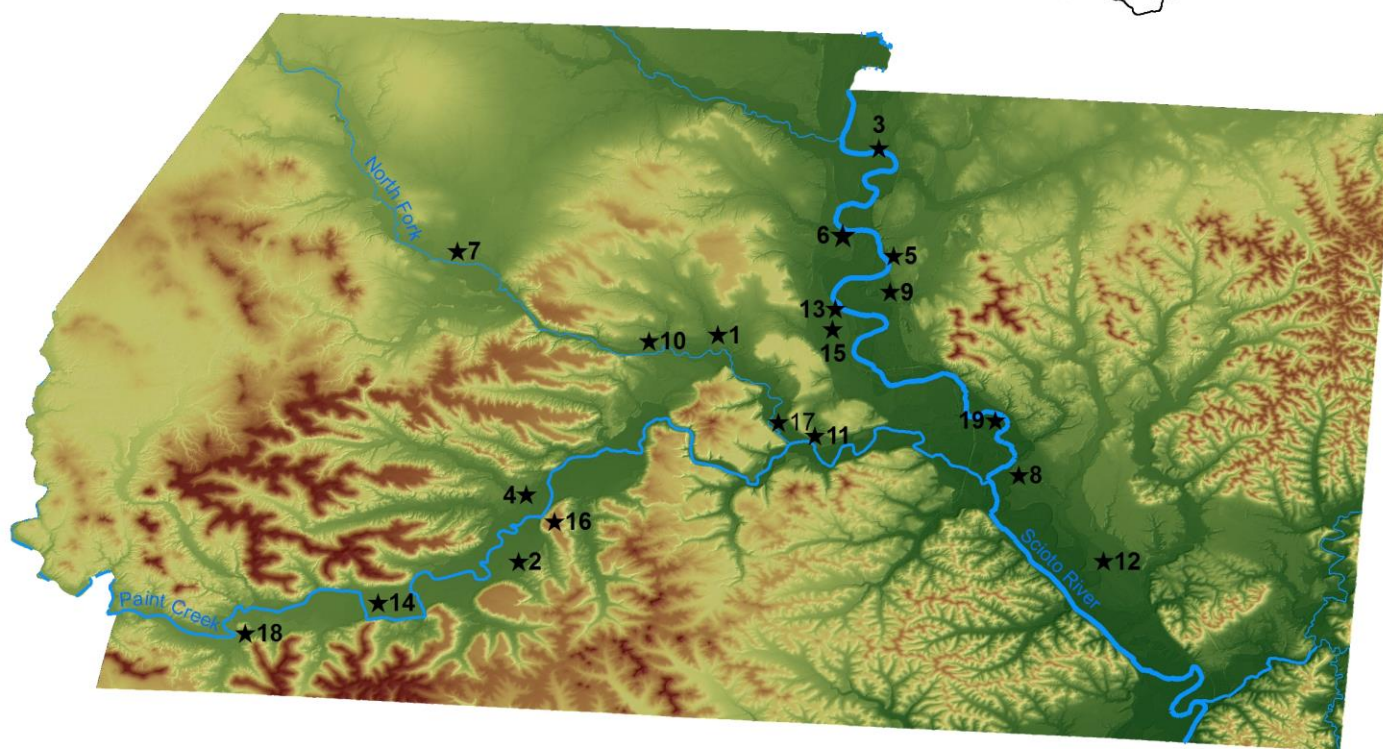
# Investigating the Placement of Hopewell Earthworks: A GIS Spatial Analysis of Ross County, Ohio



Map Author: **Timothy D. Everhart**

NAD 1983 UTM 17N

20 March 2014



## Earthwork Name

- |                            |                        |
|----------------------------|------------------------|
| ★ 1. Anderson              | ★ 11. Junction Group   |
| ★ 2. Baum                  | ★ 12. Liberty          |
| ★ 3. Blackwater            | ★ 13. Mound City       |
| ★ 4. Bourneville Circle    | ★ 14. Seip             |
| ★ 5. Cedar Bank            | ★ 15. Shriver's Circle |
| ★ 6. Dunlap                | ★ 16. Spruce Hill      |
| ★ 7. Frankfort             | ★ 17. Steele Group     |
| ★ 8. Highbank              | ★ 18. Trefoil          |
| ★ 9. Hopeton               | ★ 19. Works East       |
| ★ 10. Hopewell Mound Group |                        |

## **Data Sources:**

Case and Carr 2008  
USDA:NRCS  
Lute 2012  
NHDPlus



Figure 3.

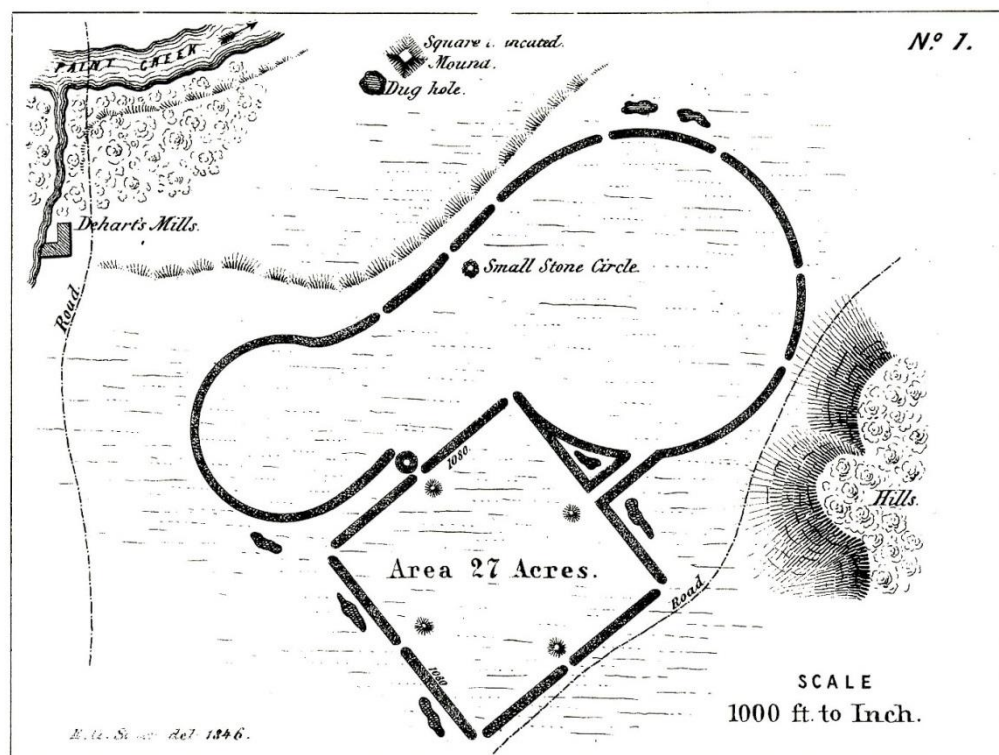


Figure 3. Map of the Baum earthwork (taken from Squier and Davis 1848).

Figure 4.

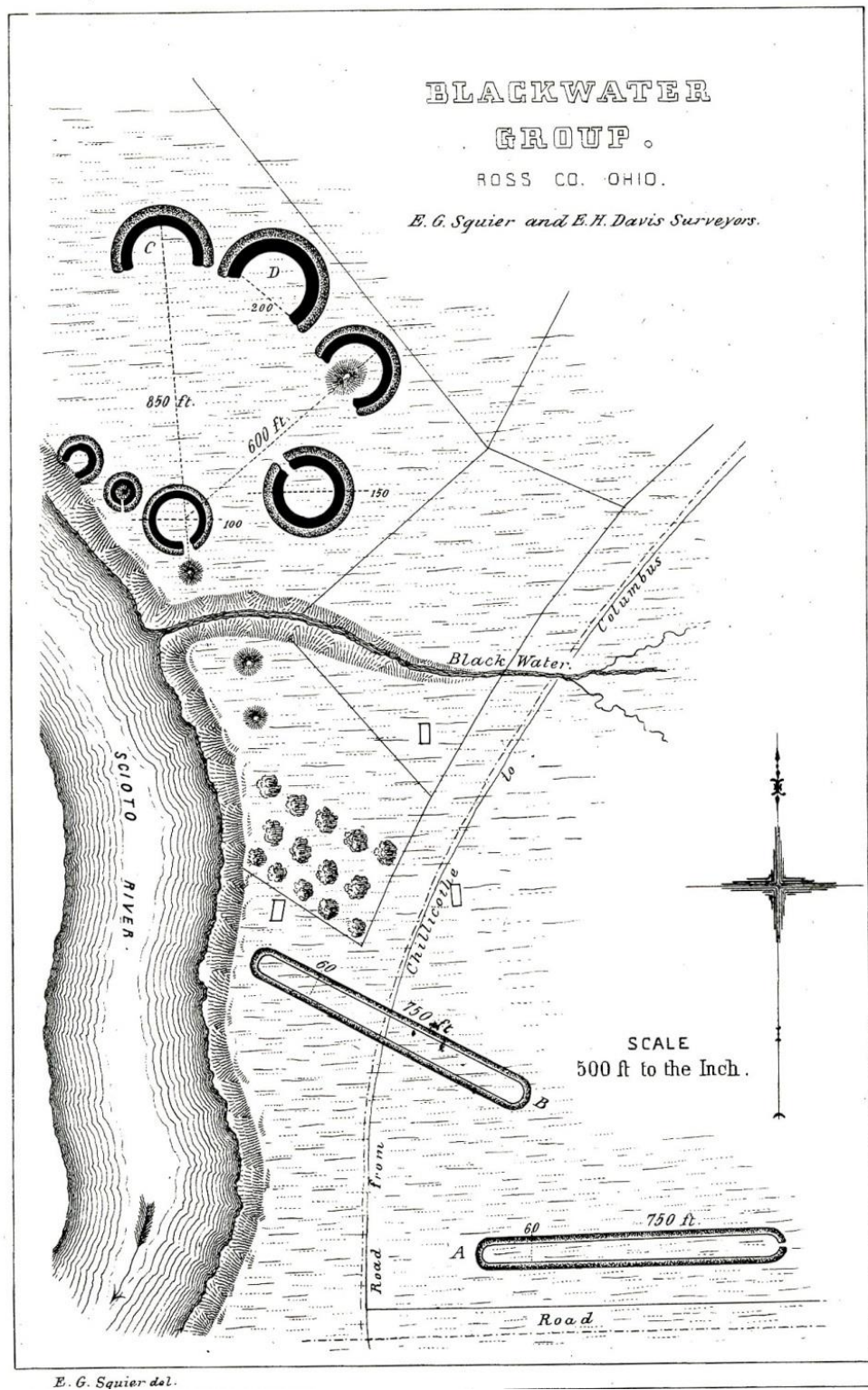


Figure 4. Map of the Blackwater earthwork (taken from Squier and Davis 1848).

Figure 5.

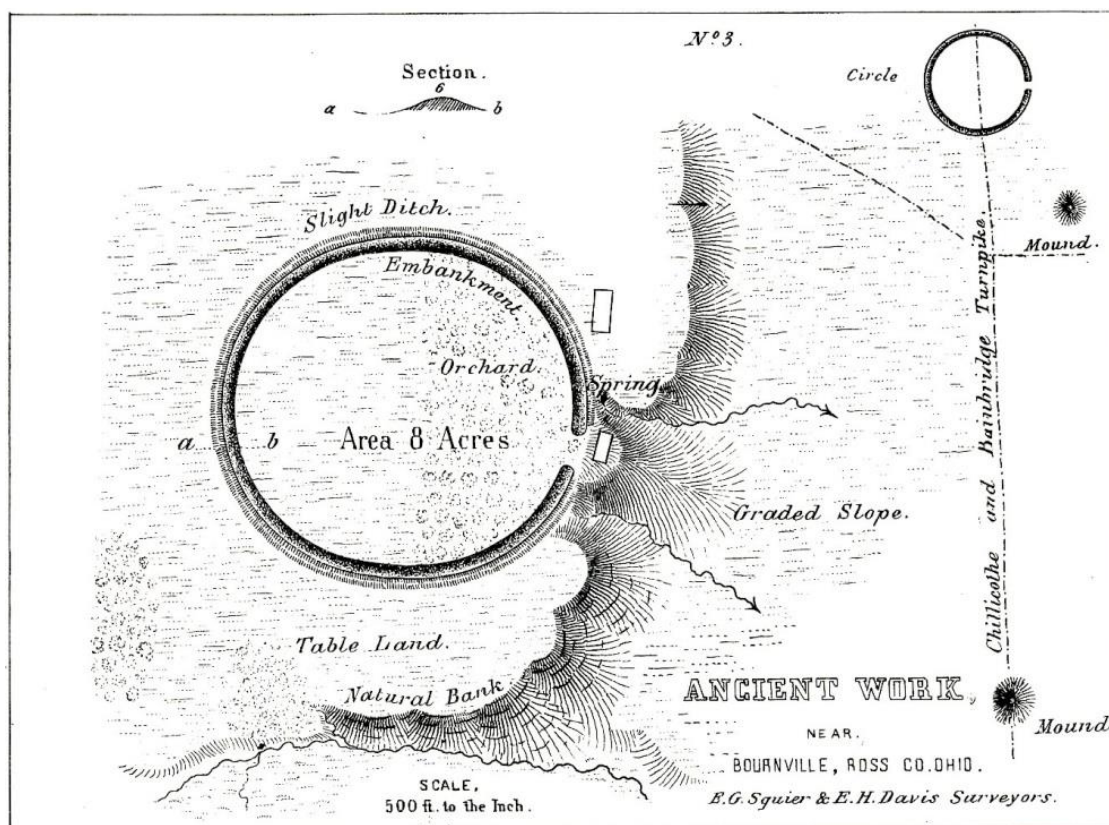


Figure 5. Map of the Bourneville Circle earthwork (taken from Squier and Davis 1848).



Figure 6.

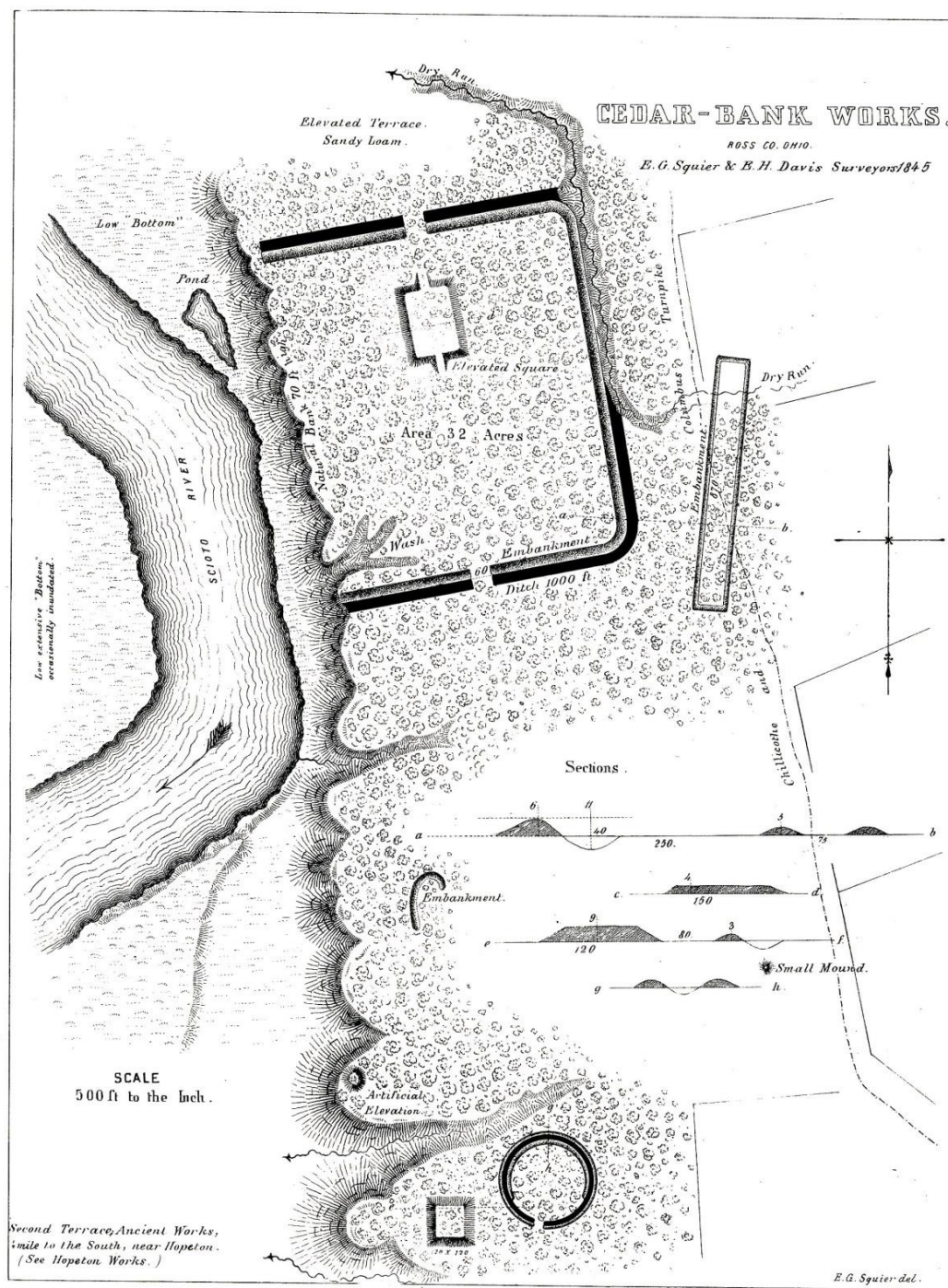


Figure 6. Map of the Cedar Bank earthwork (taken from Squier and Davis 1848).

Figure 7.

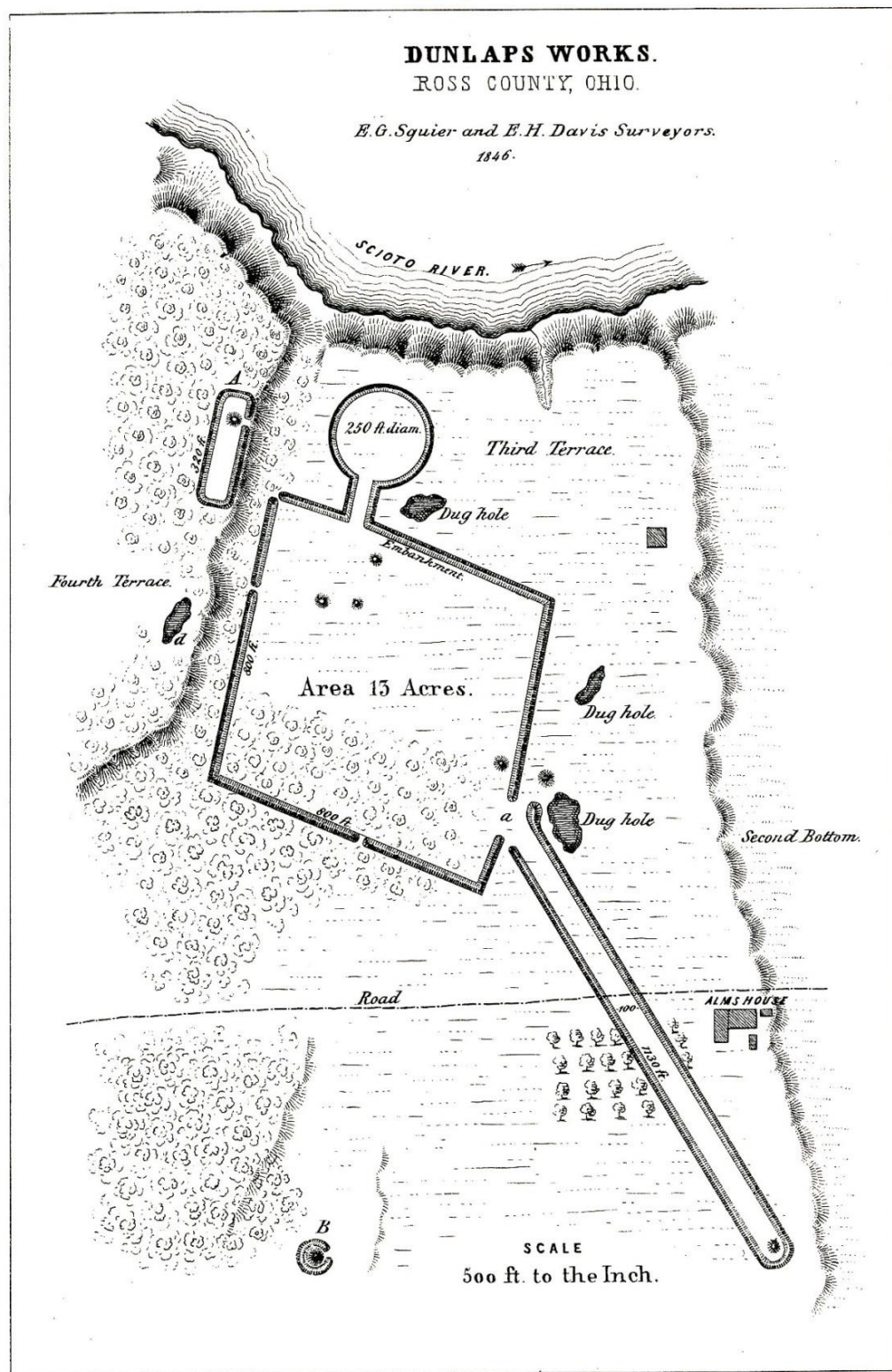


Figure 7. Map of the Dunlap earthwork (taken from Squier and Davis 1848).

Figure 8.

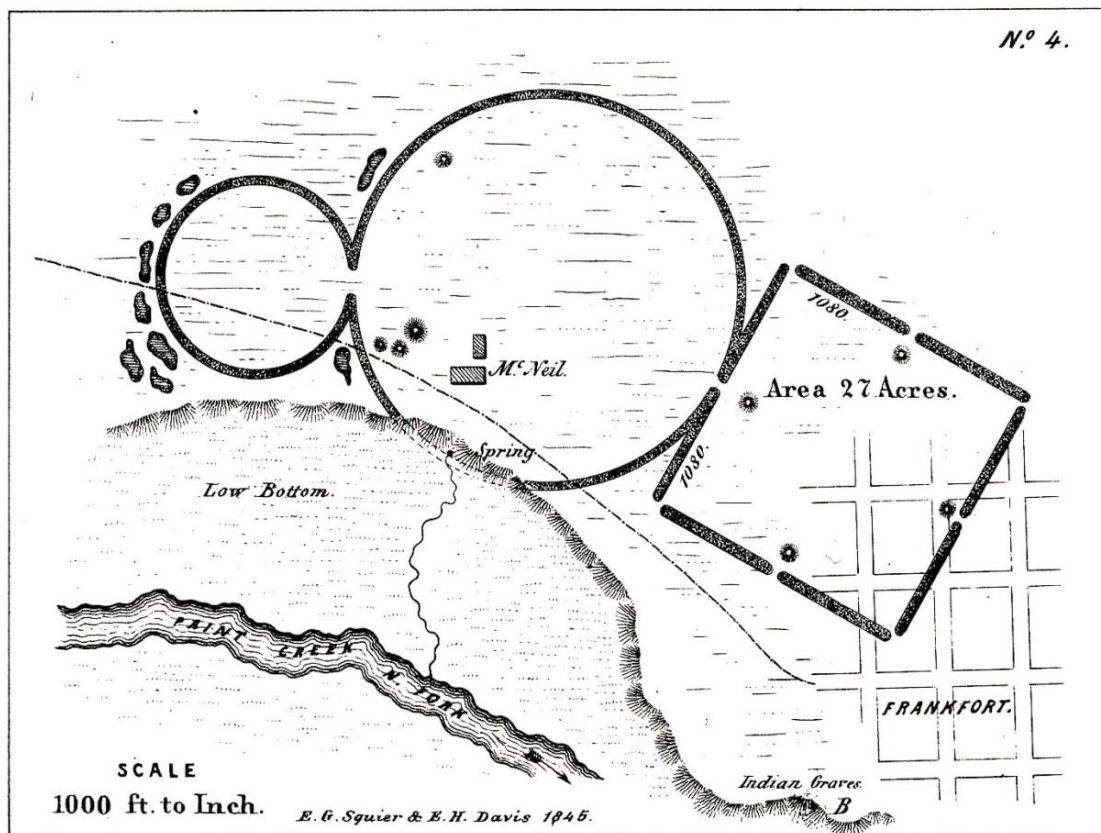


Figure 8. Map of the Frankfort earthwork (taken from Squier and Davis 1848).



Figure 9.

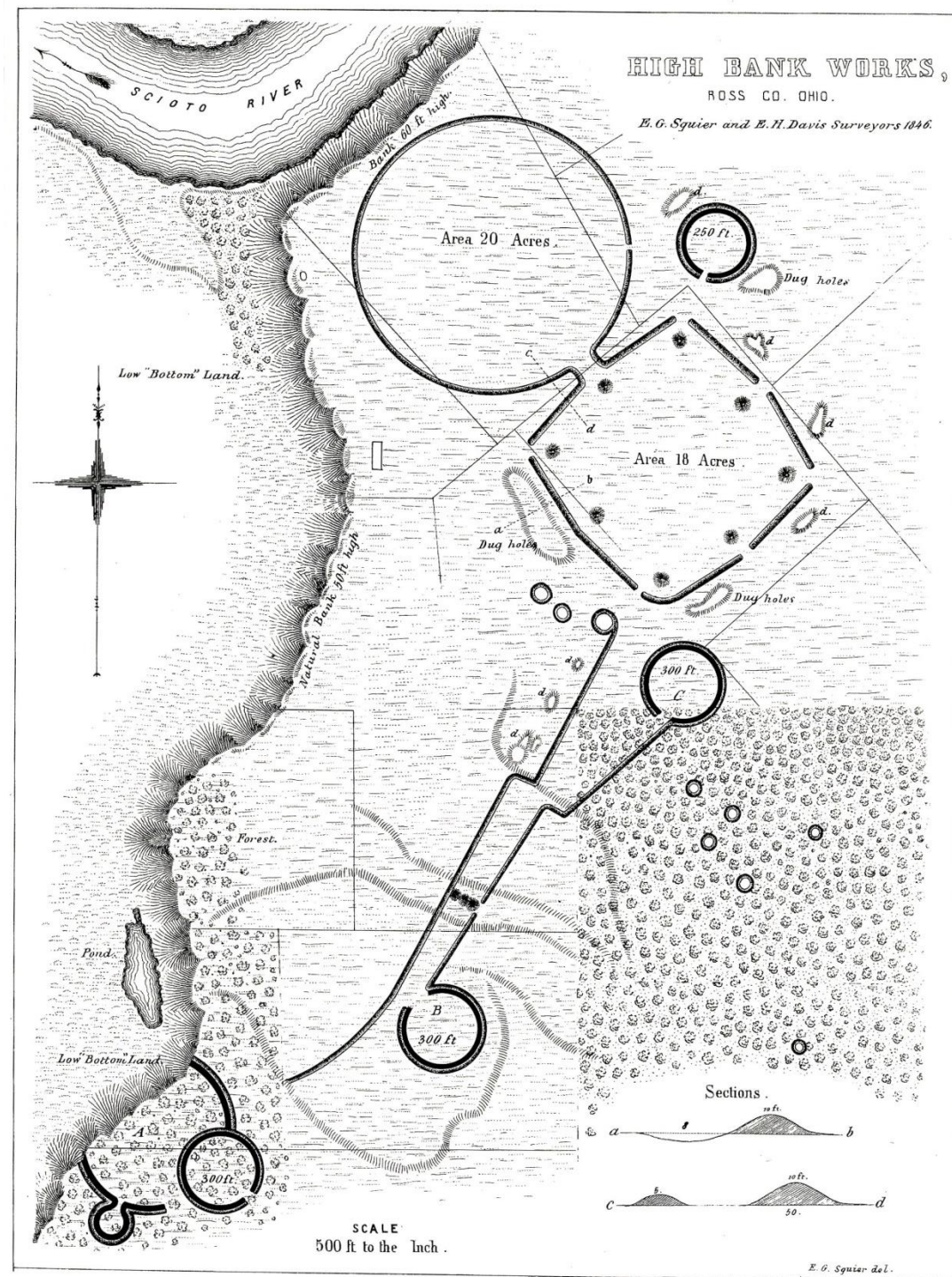


Figure 9. Map of the High Banks earthwork (taken from Squier and Davis 1848).



Figure 10.

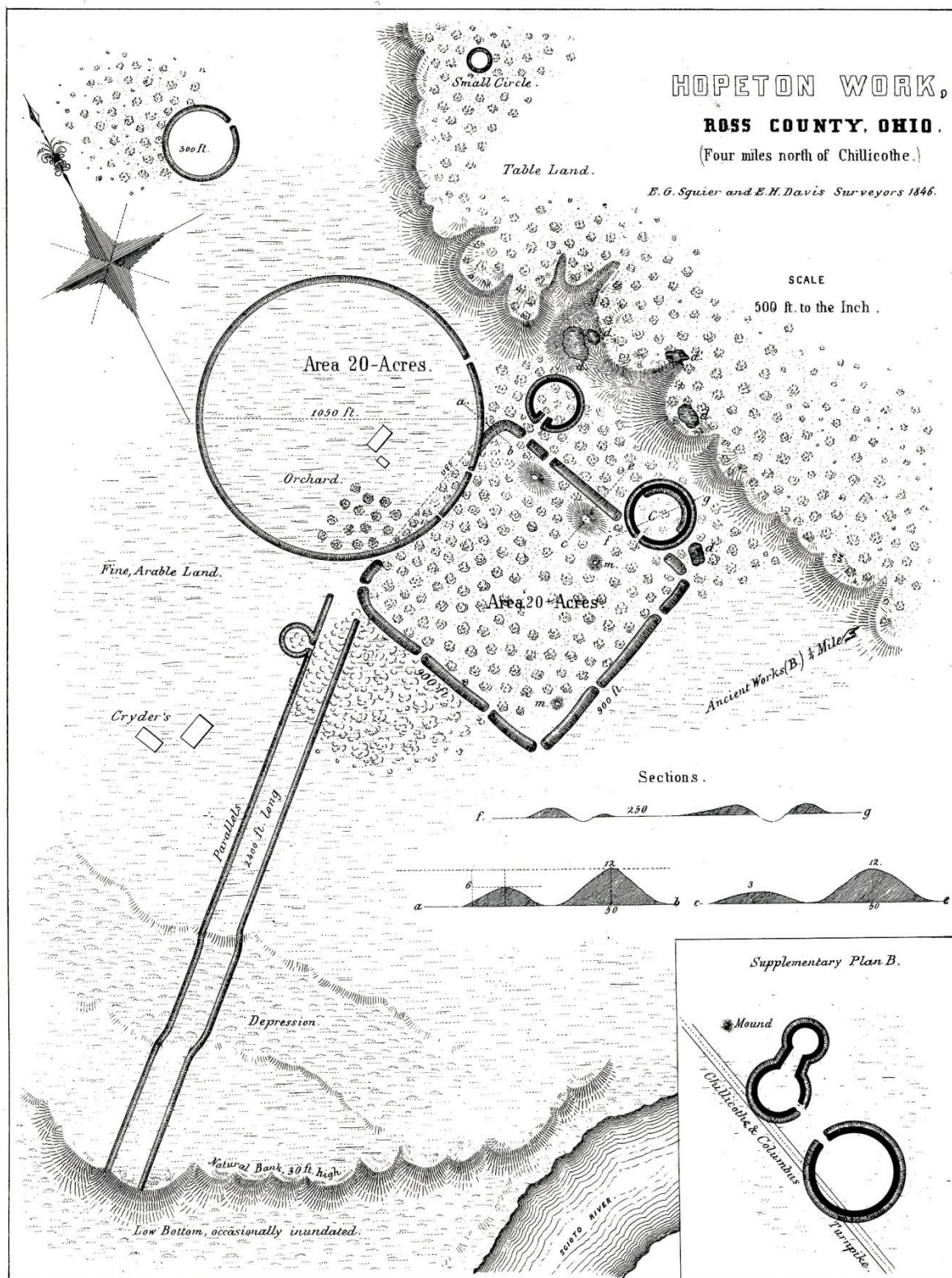


Figure 10. Map of the Hopeton earthwork (taken from Squier and Davis 1848).



Figure 11.

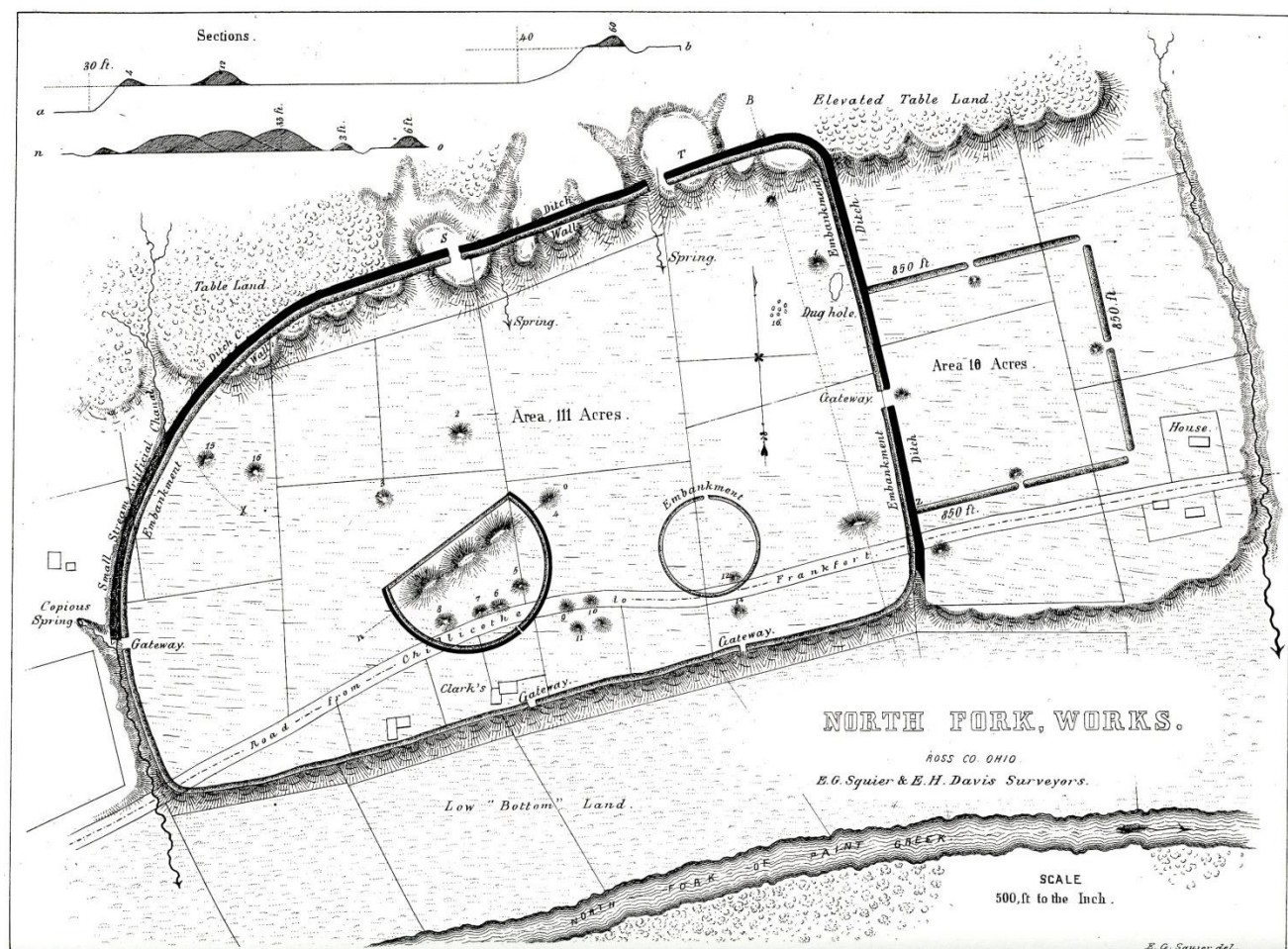


Figure 11. Map of the Hopewell Mound Group earthwork (taken from Squier and Davis 1848).

Figure 12.

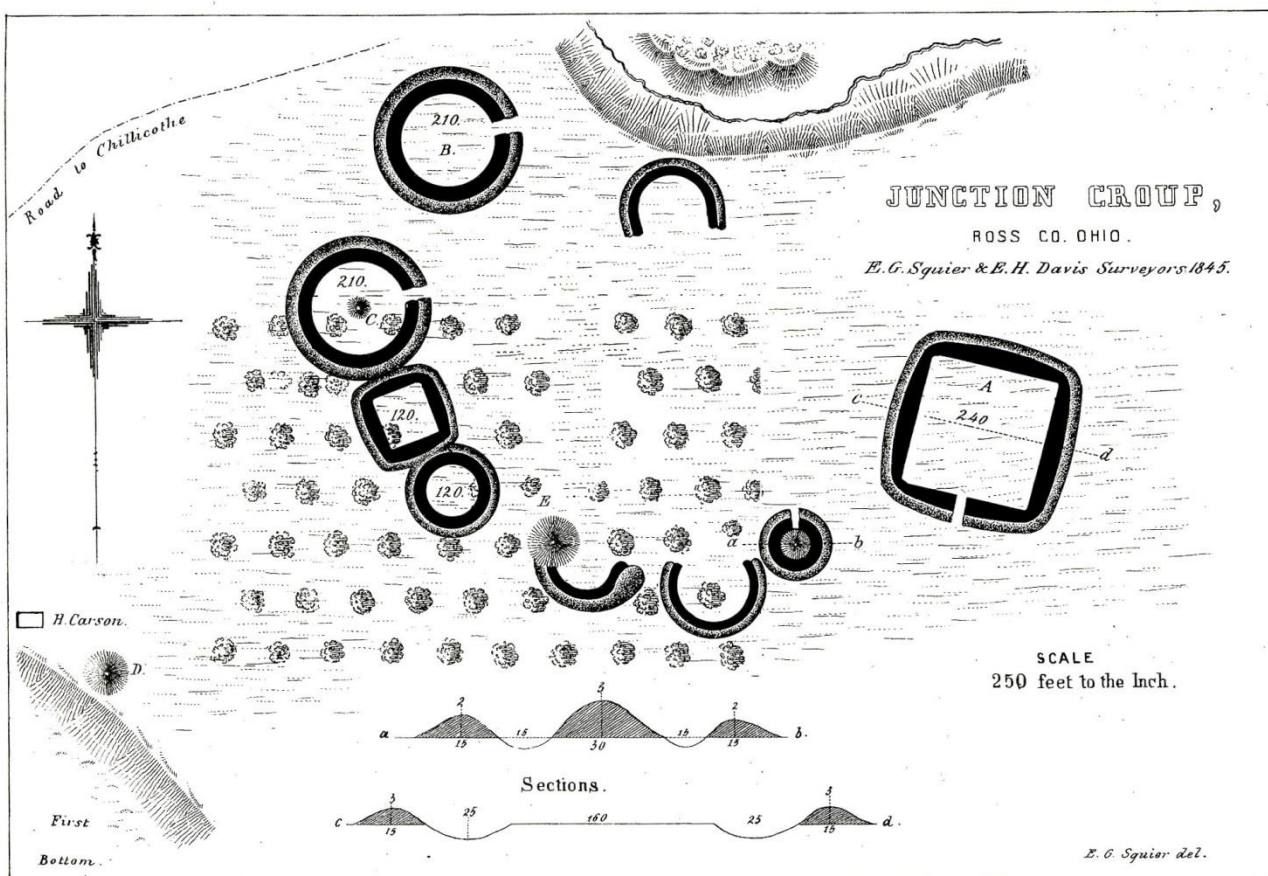


Figure 12. Map of the Junction Group earthwork (taken from Squier and Davis 1848).



Figure 13.

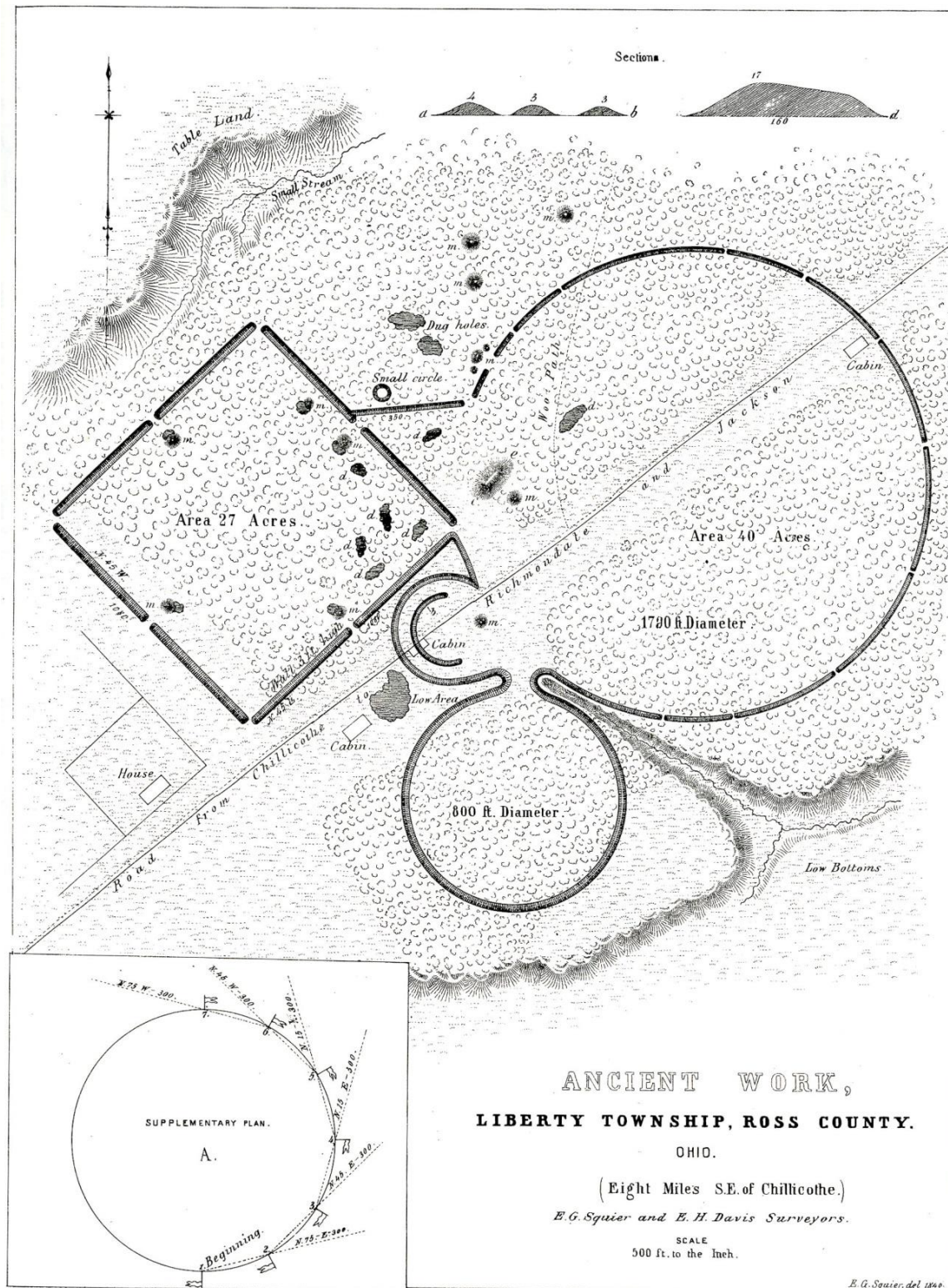


Figure 13. Map of the Liberty earthwork (taken from Squier and Davis 1848).

Figure 14.

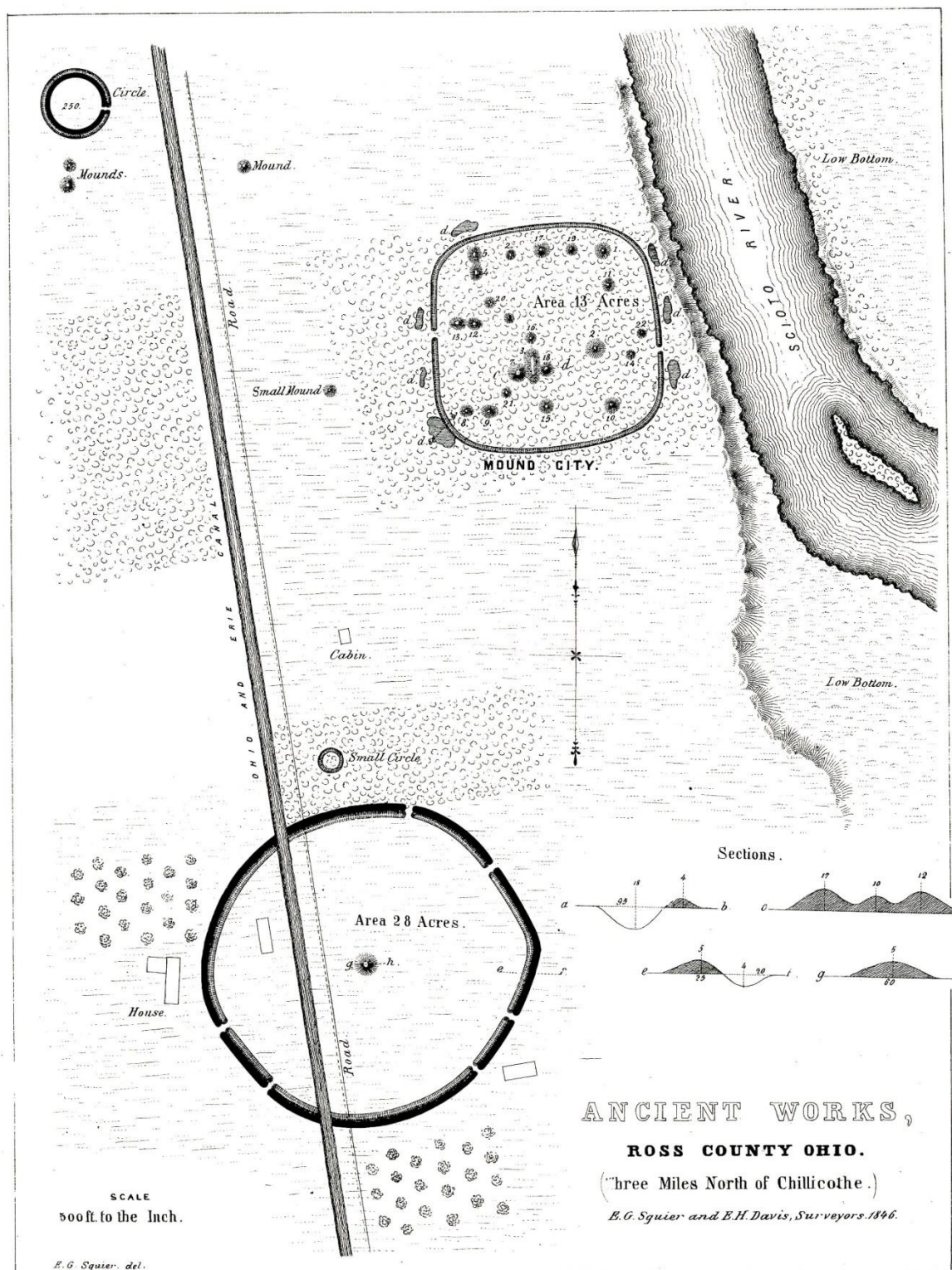


Figure 14. Map of the Mound City and Shriver's Circle earthworks (taken from Squier and Davis 1848).



Figure 15.

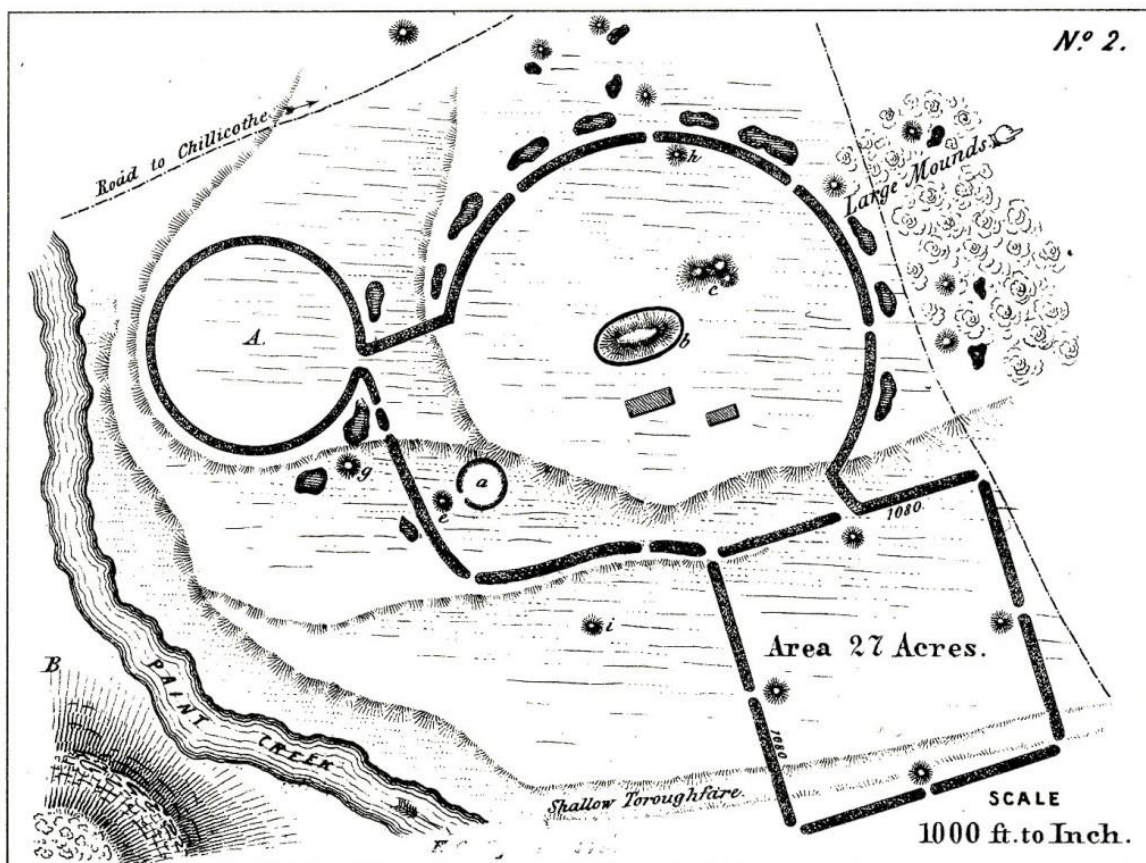


Figure 15. Map of the Seip earthwork (taken from Squier and Davis 1848).

Figure 16.

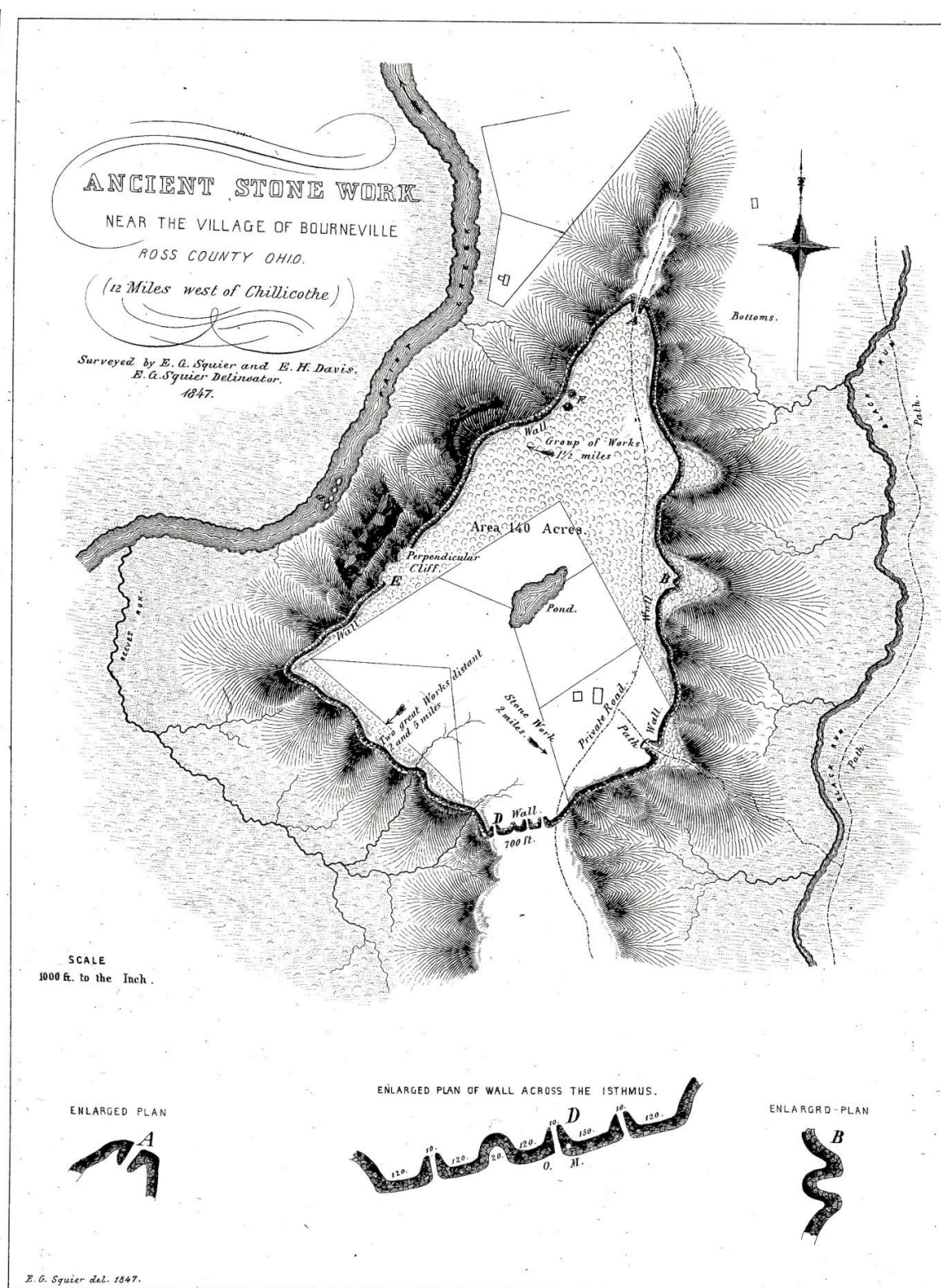


Figure 16. Map of the Spruce Hill earthwork (taken from Squier and Davis 1848).



Figure 17.

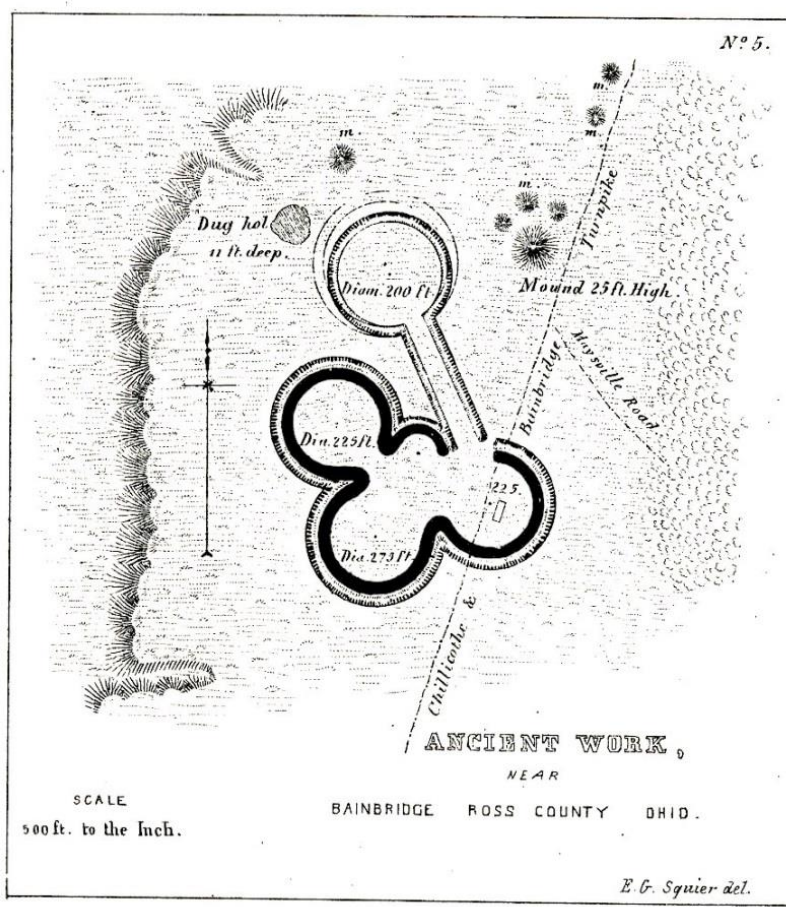


Figure 17. Map of the Trefoil earthwork (taken from Squier and Davis 1848).

Figure 18.

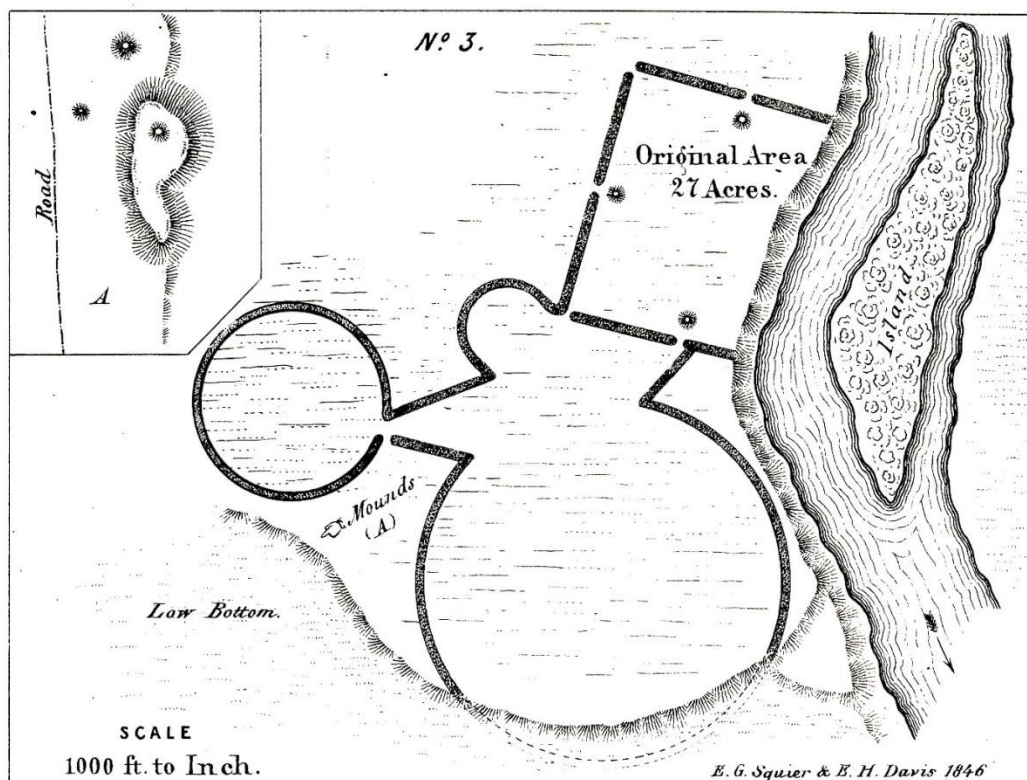
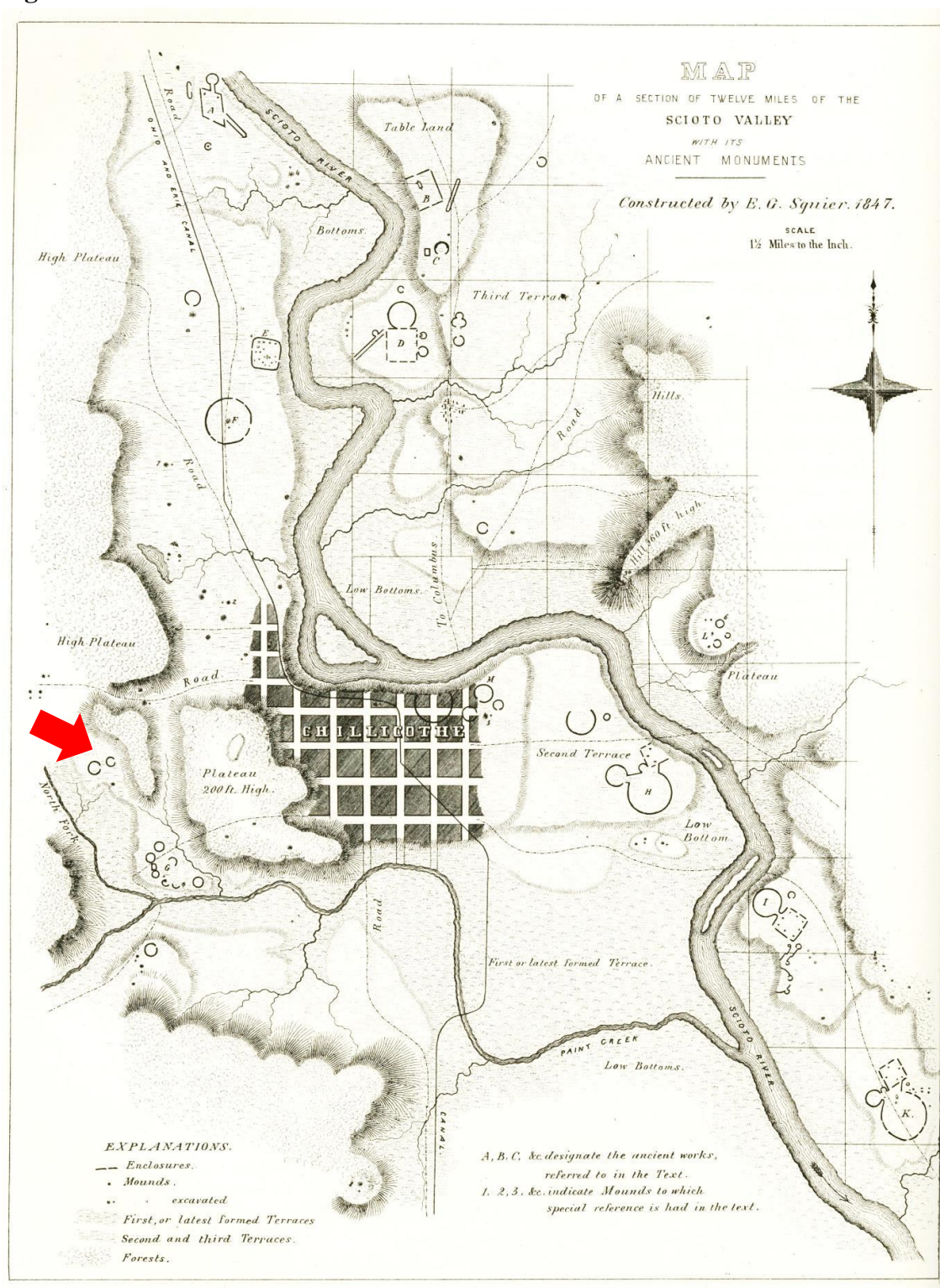


Figure 18. Map of the Works East earthwork (taken from Squier and Davis 1848).

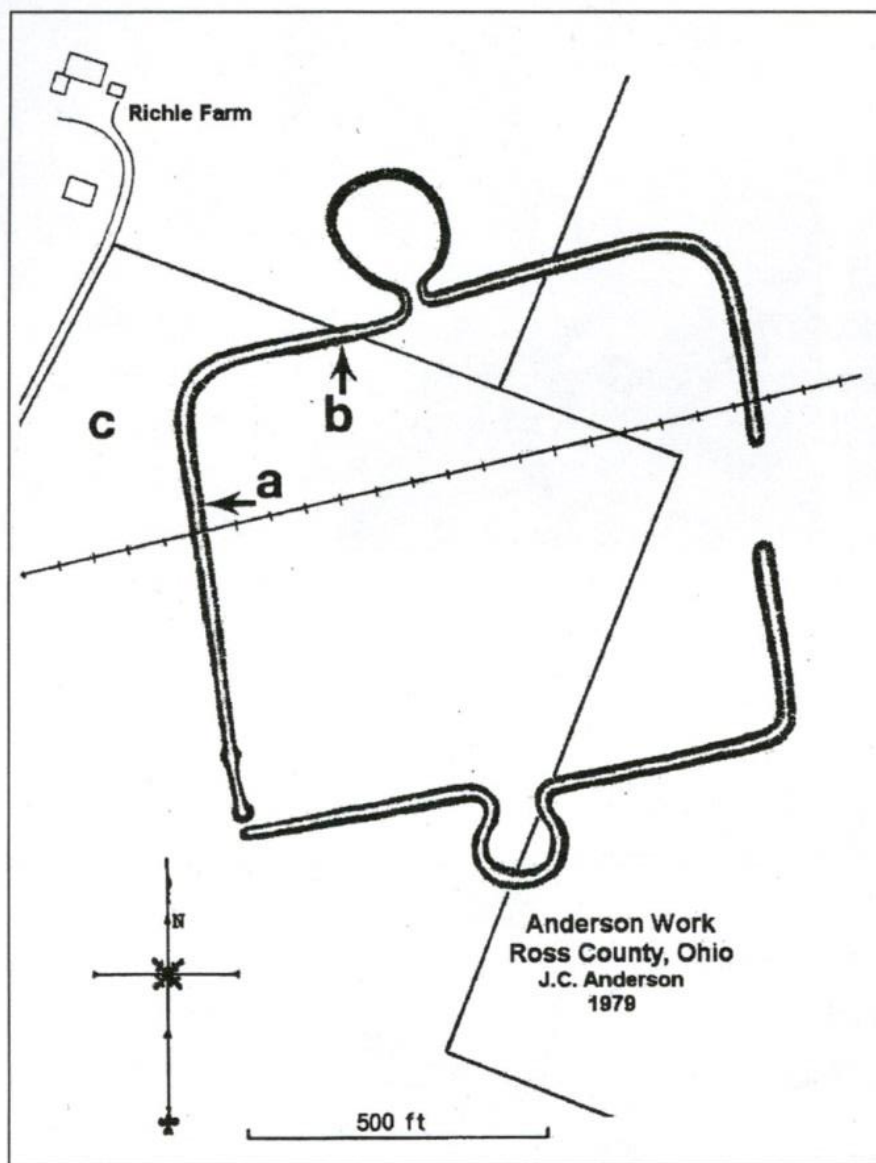


Figure 19.



**Figure 19.** Map of the earthworks of the Scioto Valley with an arrow pointing to the Steele Group earthwork (taken from Squier and Davis 1848).

**Figure 20.**



**Figure 20.** Map of the Anderson earthwork (taken from Anderson 1979, reused in Pickard and Weinberger 2009).

Figure 21.

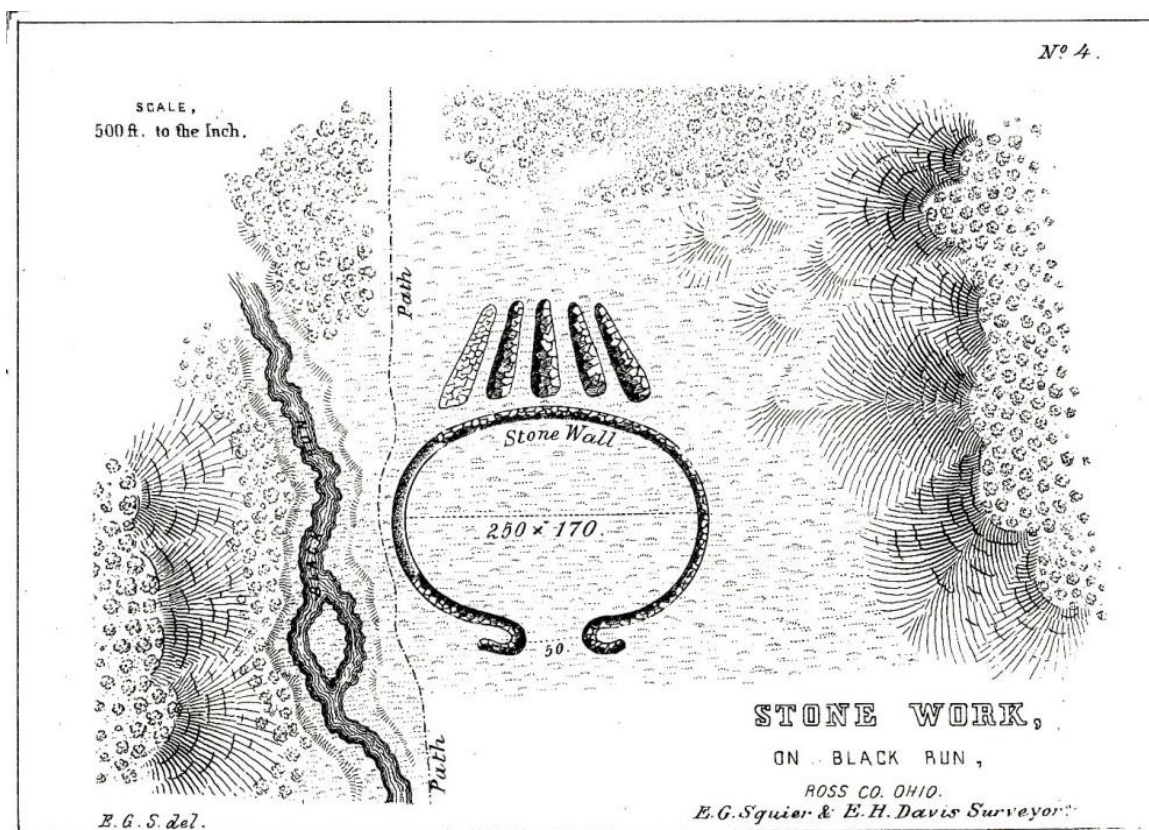


Figure 21. Map of the Stone Work earthwork (taken from Squier and Davis 1848).



Figure 22.

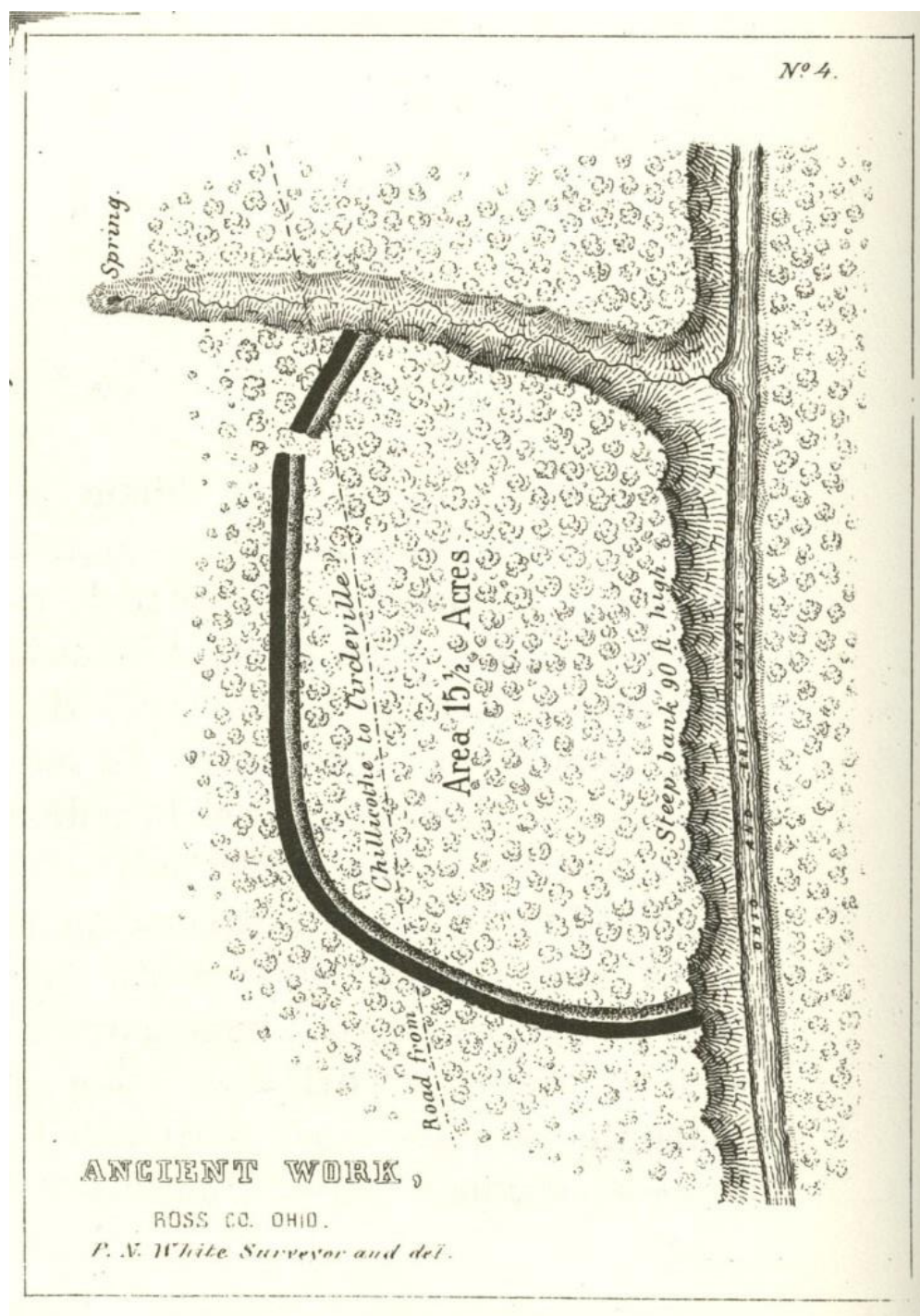


Figure 22. Map of the “Ancient Work” earthwork (taken from Squier and Davis 1848).

Figure 23.

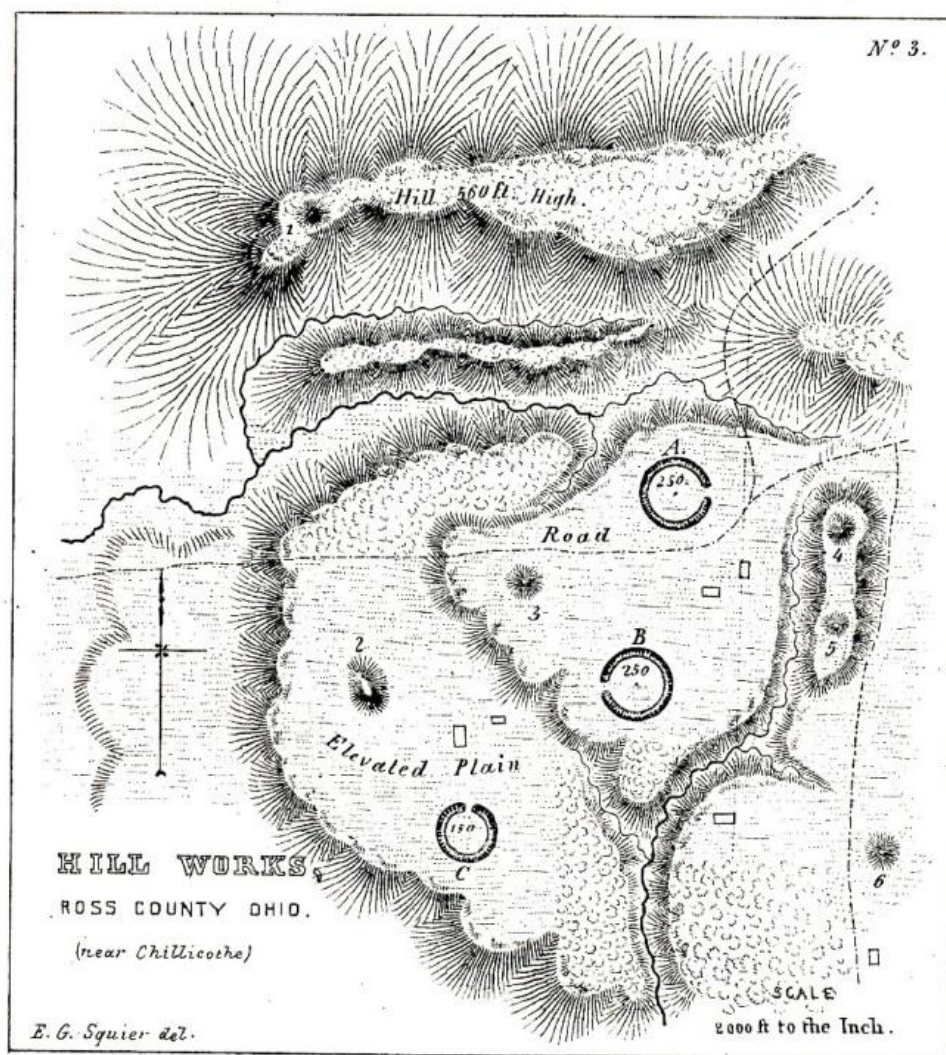


Figure 23. Map of the “Hill Works” earthwork (taken from Squier and Davis 1848).

Figure 24.

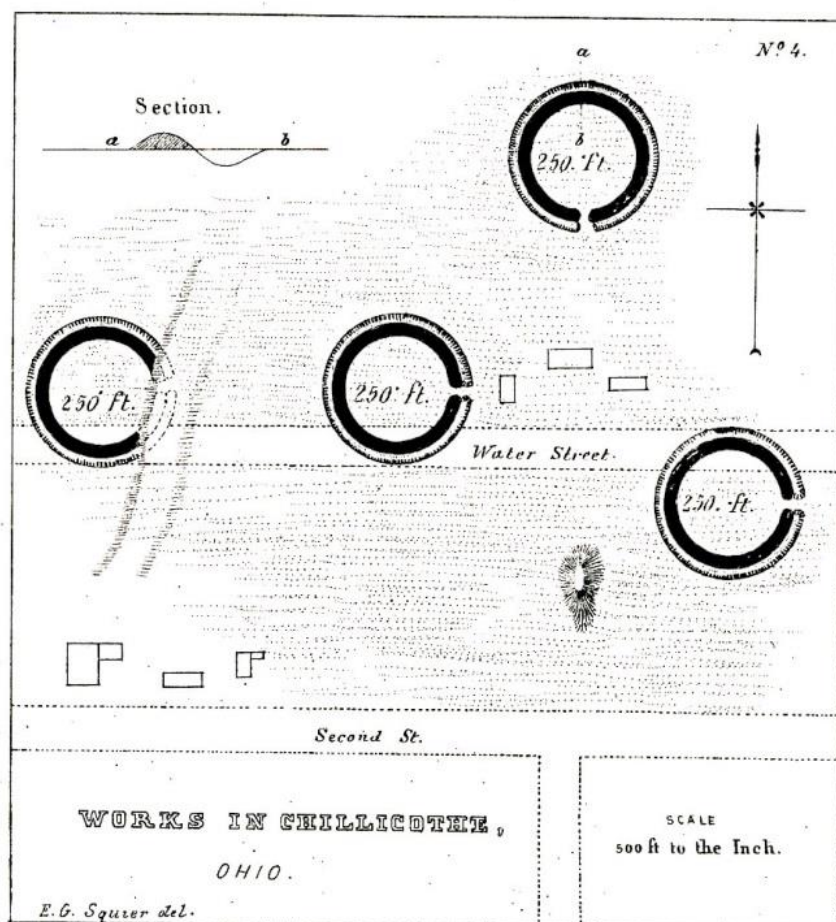
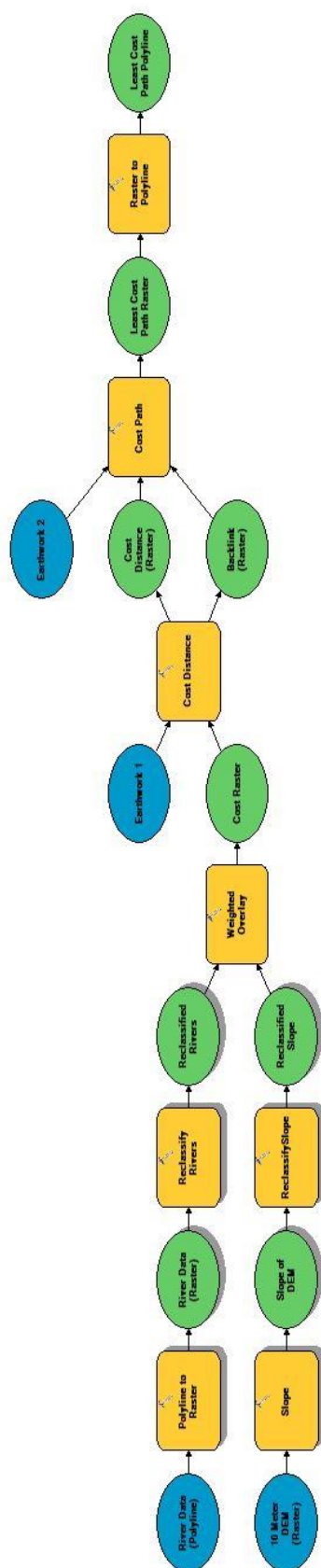


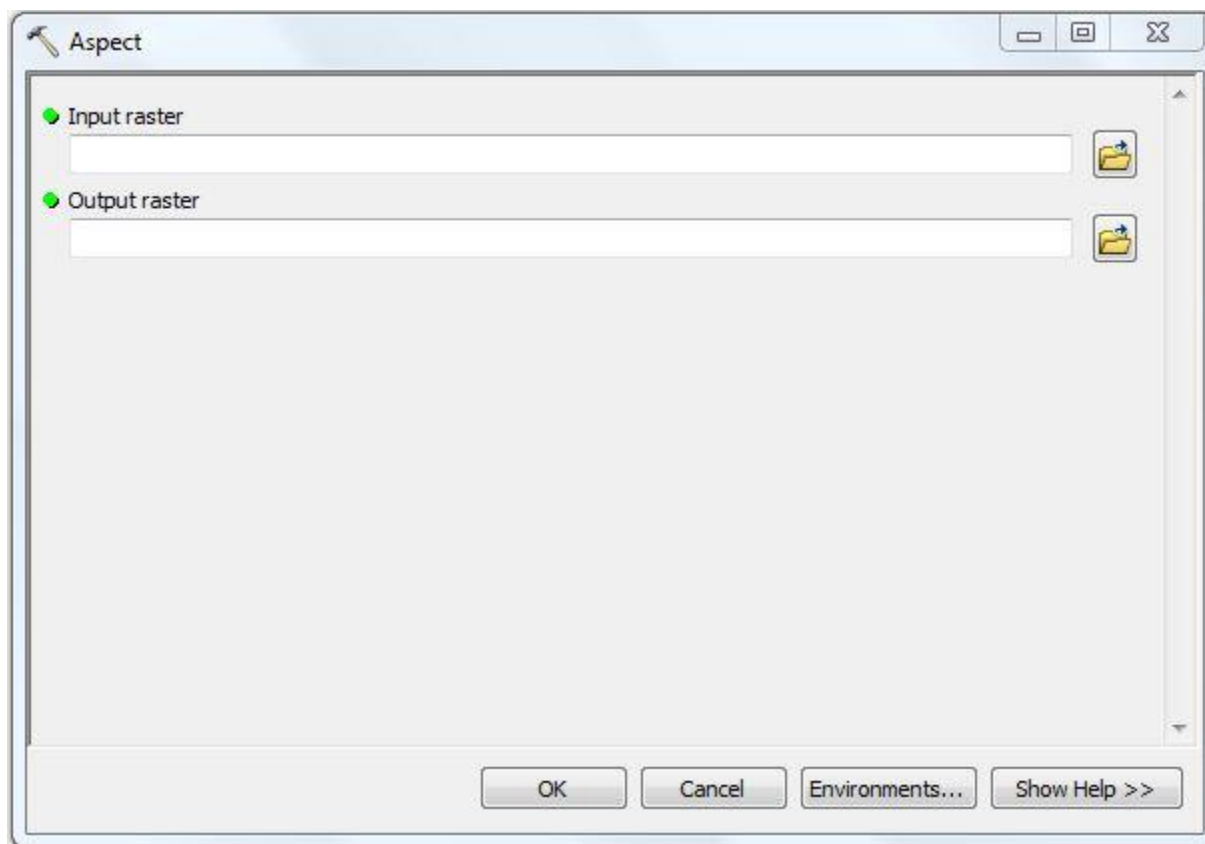
Figure 18. Map of the "Works in Chillicothe" earthwork (taken from Squier and Davis 1848).



Figure 25.



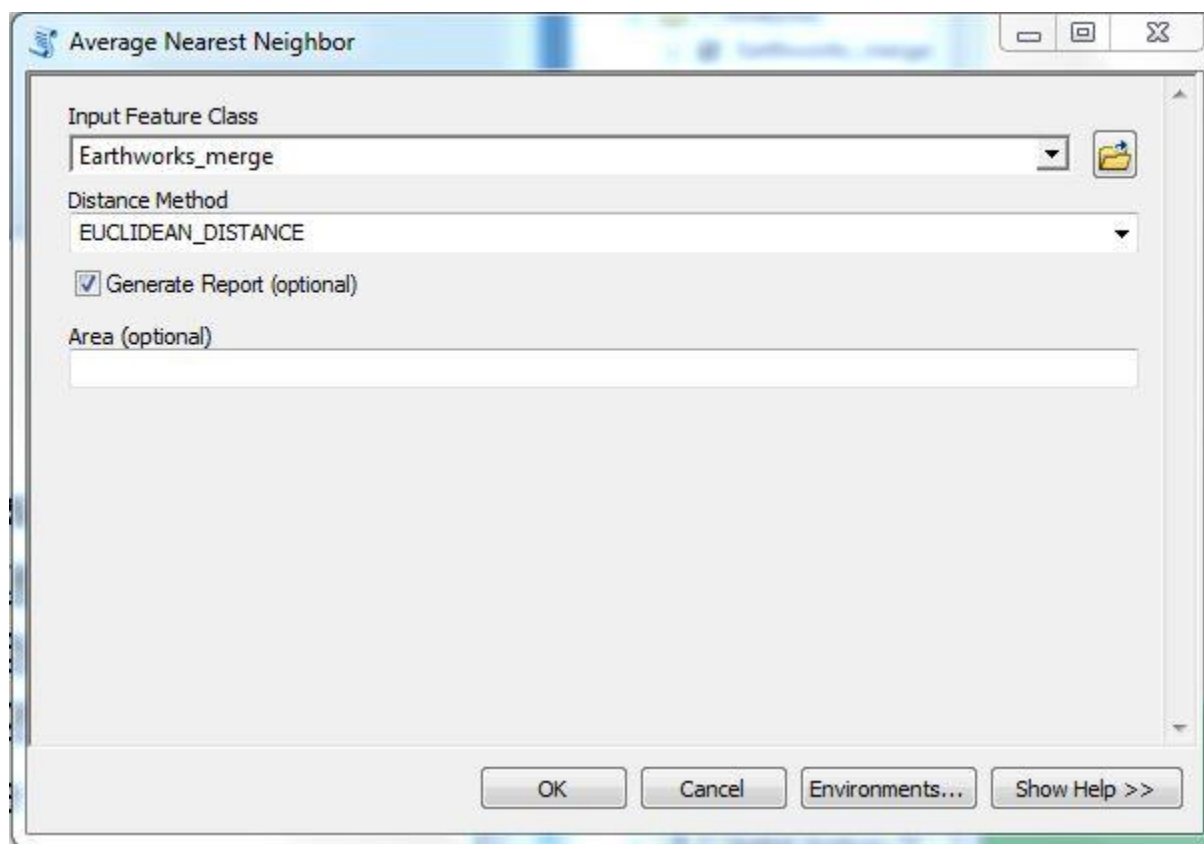
**Figure 25.** Flow chart of processes and tools involved in creating a least cost path.

**Figure 26.**

**Figure 26.** User interface of the “Aspect” tool in ArcGIS 10.1. The input raster was a DEM of Ross County, Ohio. The output raster field is where you indicate the where the file will be save and what name the file will take when it is saved.



**Figure 27.**



**Figure 27.** User interface of the “Average Nearest Neighbor” tool in ArcGIS 10.1. The only manipulated field is the “Input Feature Class” field which required an input of shapefile containing multiple points, lines, or polygons.

Figure 28

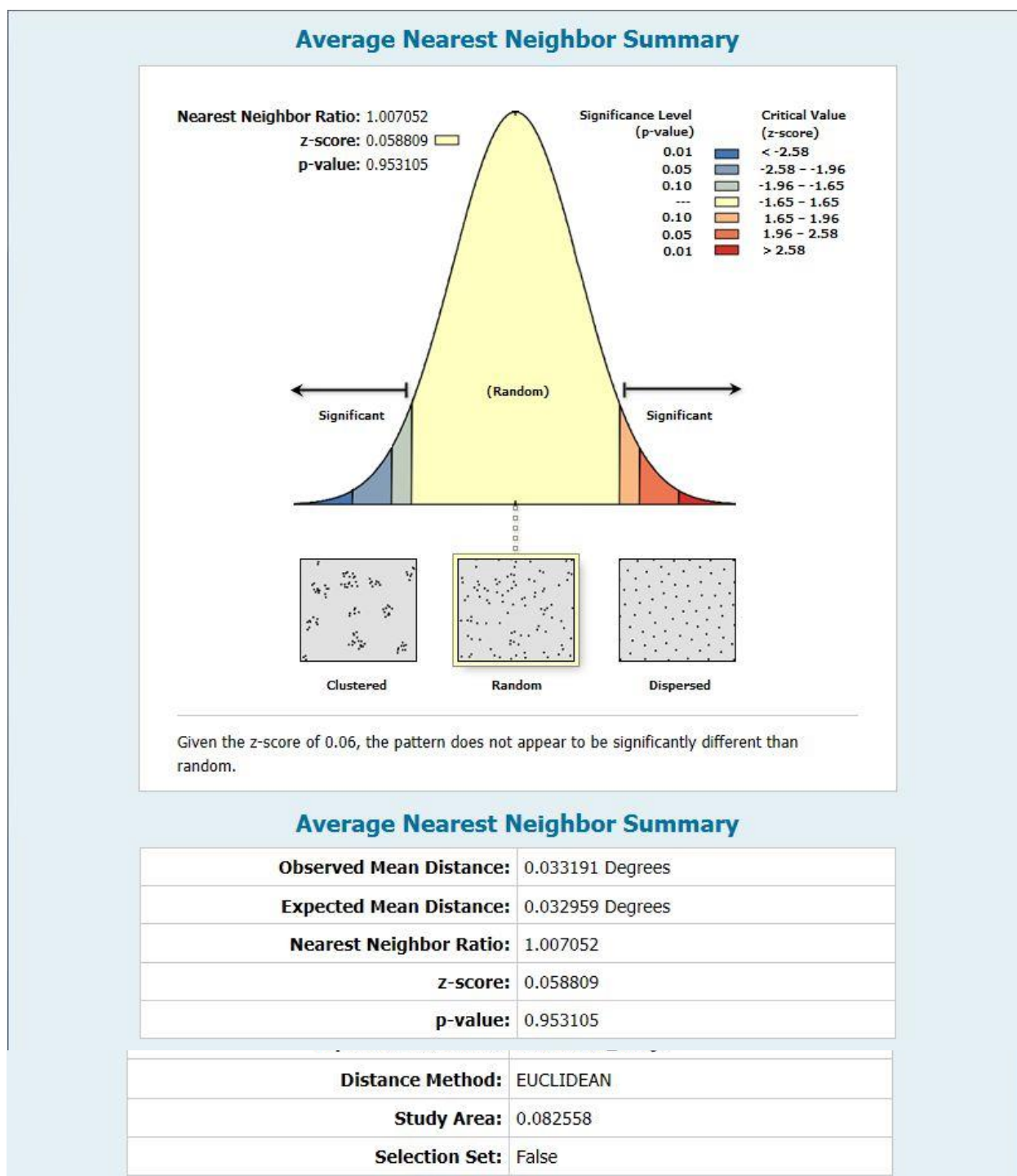
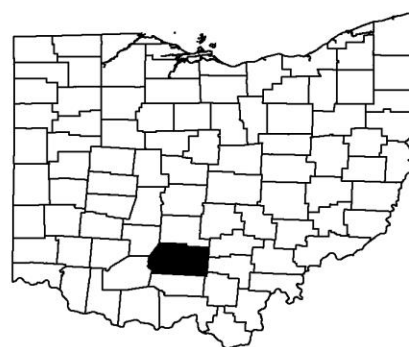


Figure 28. The automatically generated report for the “Average Nearest Neighbor” tool in ArcMap 10.1.

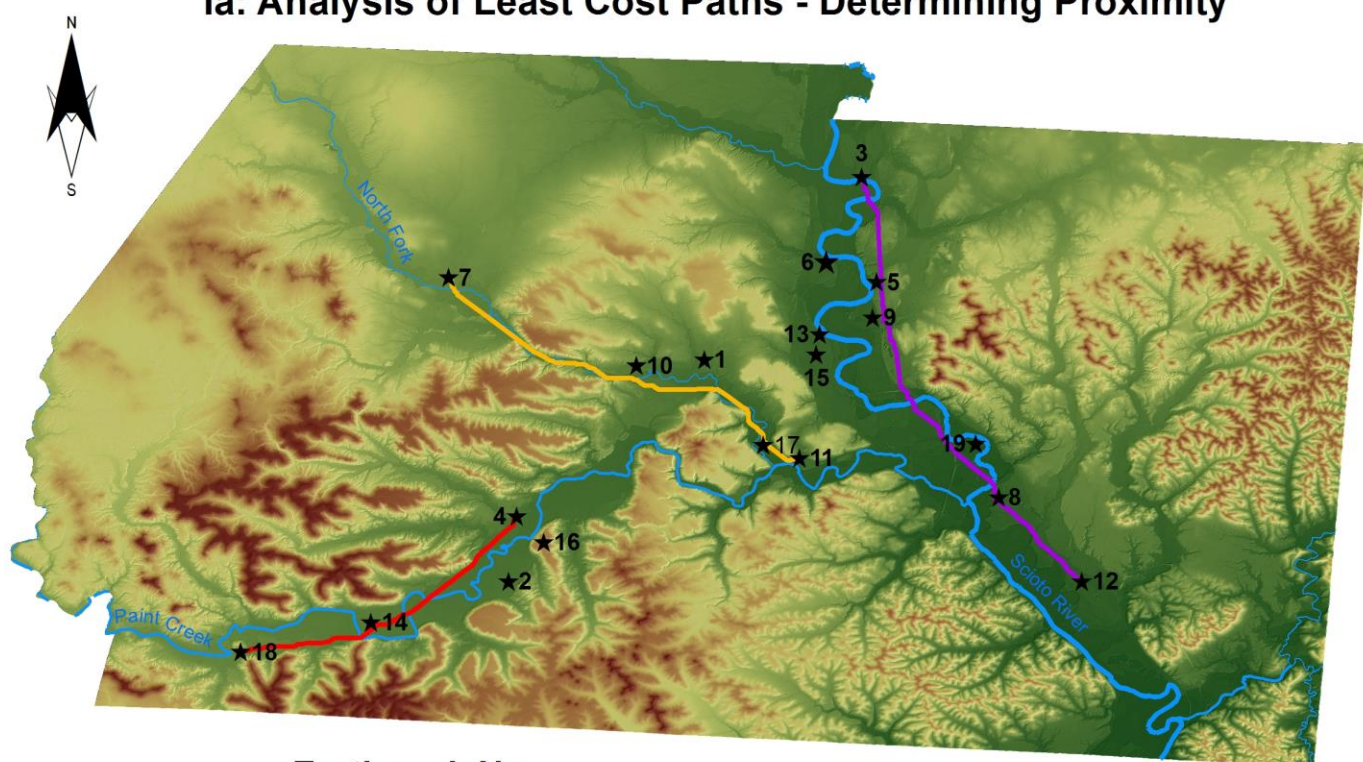
Figure 29.

# Investigating the Placement of Hopewell Earthworks: A GIS Spatial Analysis of Ross County, Ohio

Map Author: Timothy D. Everhart  
NAD 1983 UTM 17N  
20 March 2014



## Ia: Analysis of Least Cost Paths - Determining Proximity



### Earthwork Name

- |                            |                        |
|----------------------------|------------------------|
| ★ 1. Anderson              | ★ 11. Junction Group   |
| ★ 2. Baum                  | ★ 12. Liberty          |
| ★ 3. Blackwater            | ★ 13. Mound City       |
| ★ 4. Bourneville Circle    | ★ 14. Seip             |
| ★ 5. Cedar Bank            | ★ 15. Shriver's Circle |
| ★ 6. Dunlap                | ★ 16. Spruce Hill      |
| ★ 7. Frankfort             | ★ 17. Steele Group     |
| ★ 8. Highbank              | ★ 18. Trefoil          |
| ★ 9. Hopeton               | ★ 19. Works East       |
| ★ 10. Hopewell Mound Group |                        |

0 5 10 20  
Kilometers

### Least Cost Paths

- Paint Creek Path
- North Fork Path
- Scioto Path

### Data Sources:

Case and Carr 2008  
USDA:NRCS  
Lute 2012  
NHDPlus

**Figure 30.****Figure 30.** Results from Analysis Ia: Analysis of Least Cost Paths – Determining Proximity

<b>Earthwork Name (#)</b>	<b>Distance to River (Meters)</b>	<b>Distance to Least Cost Path (Meters) [Path Name]</b>
<b>Anderson (1)</b>	812.5	1570.7 [North Fork]
<b>Baum (2)</b>	1135.3	1755.6 [Paint Creek]
<b>Blackwater (3)</b>	N/A	N/A [Scioto]
<b>Bourneville Circle (4)</b>	N/A	N/A [Paint Creek]
<b>Cedar Bank (5)</b>	388.8	174.8 [Scioto]
<b>Dunlap (6)</b>	300.9	2219.4 [Scioto]
<b>Frankfort (7)</b>	N/A	N/A [North Fork]
<b>High Banks (8)</b>	711.6	192.6 [Scioto]
<b>Hopeton (9)</b>	996.9	425.1 [Scioto]
<b>Hopewell Mound Group (10)</b>	590.4	703.4 [North Fork]
<b>Junction (11)</b>	N/A	N/A [North Fork]
<b>Liberty (12)</b>	N/A	N/A [Scioto]
<b>Mound City (13)</b>	225.5	2750.6 [Scioto]
<b>Seip (14)</b>	658.6	267.2 [Paint Creek]
<b>Shriver's Circle (15)</b>	1174.8	3285.0 [Scioto]
<b>Spruce Hill (16)</b>	603.9	1594.1 [Paint Creek]
<b>Steele Group (17)</b>	364.5	133.5 [North Fork]
<b>Trefoil (18)</b>	N/A	N/A [Paint Creek]
<b>Works East (19)</b>	373.6	952.6 [Scioto]



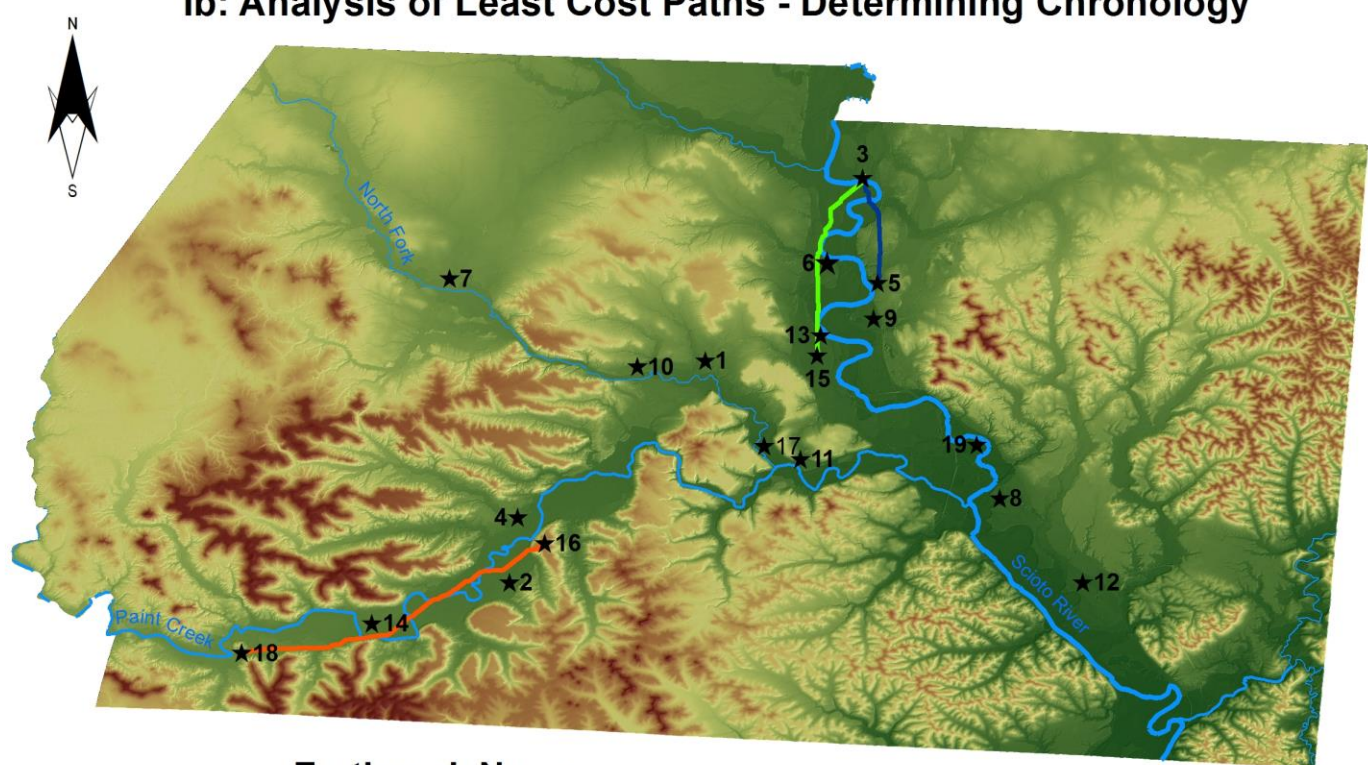
Figure 31.

# Investigating the Placement of Hopewell Earthworks: A GIS Spatial Analysis of Ross County, Ohio

Map Author: Timothy D. Everhart  
NAD 1983 UTM 17N  
20 March 2014



## Ib: Analysis of Least Cost Paths - Determining Chronology



### Earthwork Name

- |                            |                        |
|----------------------------|------------------------|
| ★ 1. Anderson              | ★ 11. Junction Group   |
| ★ 2. Baum                  | ★ 12. Liberty          |
| ★ 3. Blackwater            | ★ 13. Mound City       |
| ★ 4. Bourneville Circle    | ★ 14. Seip             |
| ★ 5. Cedar Bank            | ★ 15. Shriver's Circle |
| ★ 6. Dunlap                | ★ 16. Spruce Hill      |
| ★ 7. Frankfort             | ★ 17. Steele Group     |
| ★ 8. Highbank              | ★ 18. Trefoil          |
| ★ 9. Hopeton               | ★ 19. Works East       |
| ★ 10. Hopewell Mound Group |                        |

0 5 10 20  
Kilometers

### Least Cost Paths

- Path 1
- Path 2
- Path 3

### Data Sources:

Case and Carr 2008  
USDA:NRCS  
Lute 2012  
NHDPlus

**Figure 32.**

<b>Path Name</b>	<b>Earthwork Name (#)</b>	<b>Distance to River (Meters)</b>	<b>Distance to Least Cost Path (Meters)</b>
<b>Path 1: Blackwater to Shriver's Circle</b>			
	Cedar Bank (5)	388.8	2507.1
	Dunlap (6)	300.9	426.6
	Hopeton (9)	996.9	2357.3
	Mound City (13)	225.5	150.4
<b>Path 2: Spruce Hill to Trefoil</b>			
	Baum (2)	1135.3	738.9
	Seip (14)	658.6	685.8
<b>Path 3: Anderson to Cedar Bank</b>			
	Dunlap (6)	300.9	2143.4

**Figure 32.** Results from Analysis Ib: Analysis of Least Cost Paths – Determining Chronology

**Figure 33.**

Statistic Name	Statistic Value
Nearest Neighbor Ratio	1.007052
Nearest Neighbor Z-Score	0.058809
P-value	0.953195

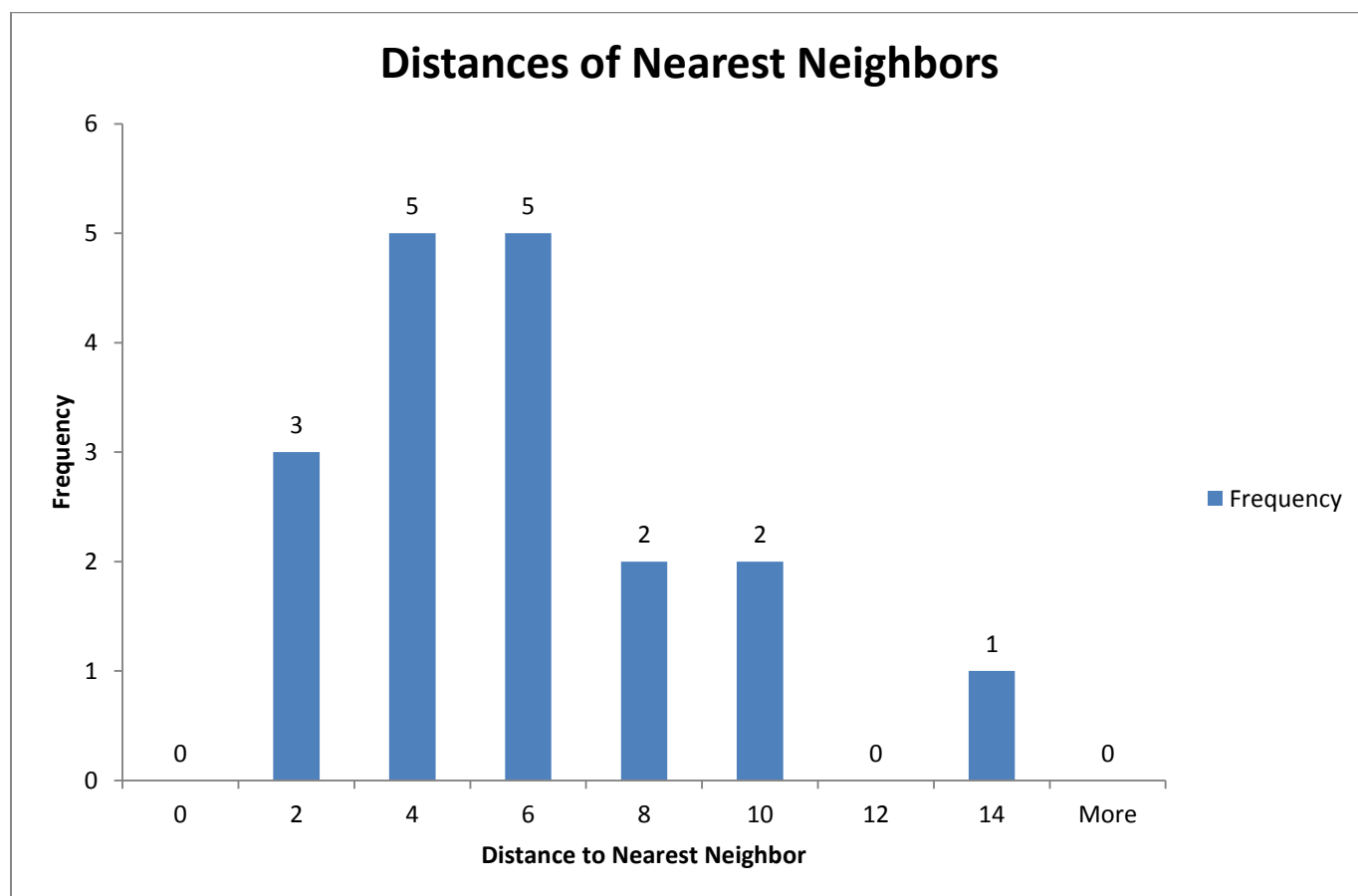
**Figure 33.** Results from Analysis IIa: Analysis of Spatiality – Average Nearest Neighbor

**Figure 34.**

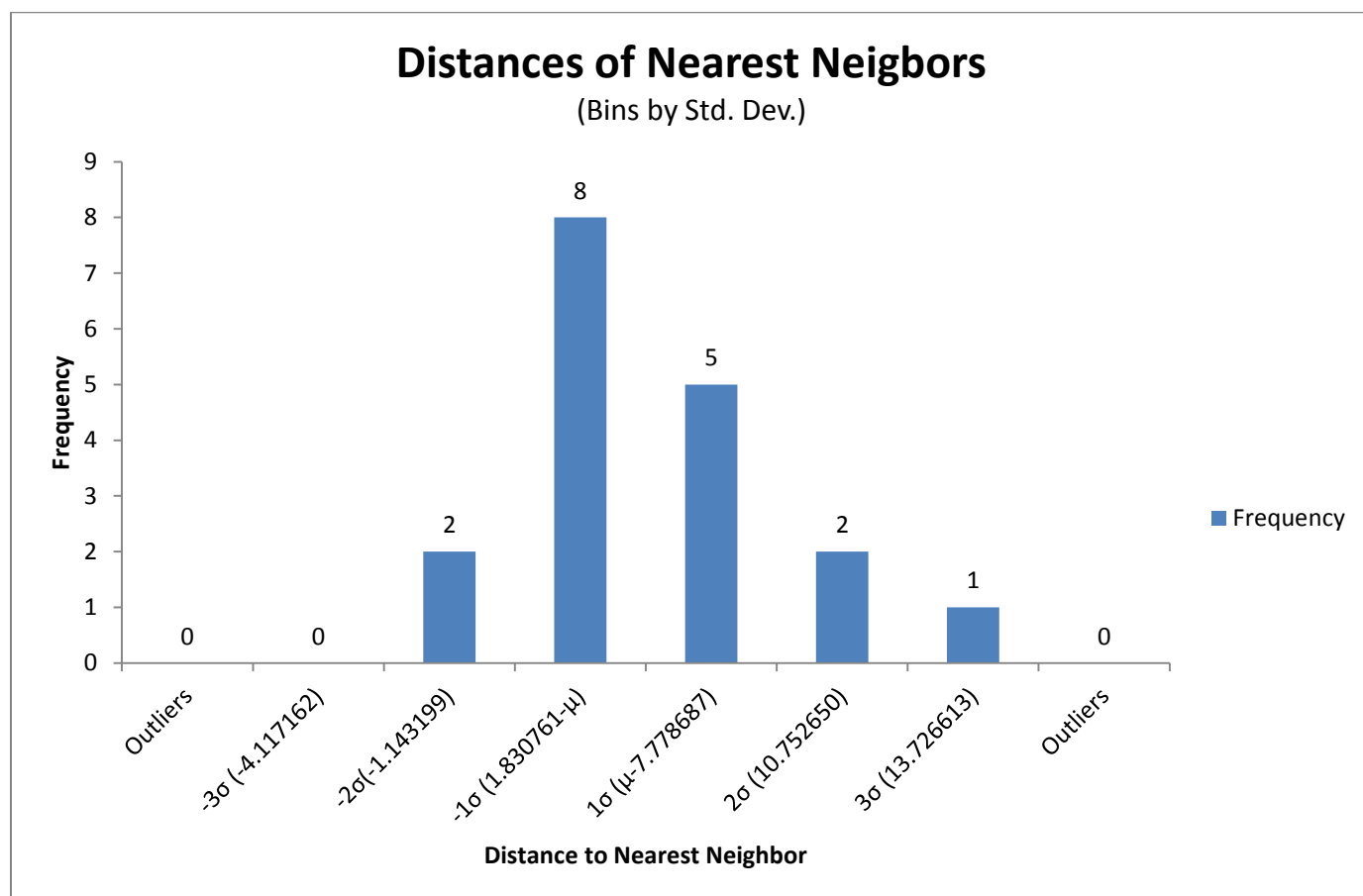
Earthwork #	Earthwork Name	Distance to Nearest Neighbor (Kilometers)	Neighbor #	Neighbor Name
18	Trefoil	5.767992	14	Seip
14	Seip	6.11452	2	Baum
2	Baum	2.552421	16	Spruce Hill
16	Spruce Hill	4.348923	4	Bourneville Circle
4	Bourneville Circle	12.157547	11	Junction Group
7	Frankfort	9.102358	10	Hopewell Mound Group
10	Hopewell Mound Group	2.838049	1	Anderson
1	Anderson	5.193377	17	Steele Group
17	Steele Group	1.652838	11	Junction Group
11	Junction Group	7.371719	19	Works East
12	Liberty	5.677098	8	High Banks
8	High Banks	3.018426	19	Works East
19	Works East	8.166382	15	Shriver's Circle
15	Shriver's Circle	1.080208	13	Mound City
13	Mound City	2.393637	9	Hopeton
9	Hopeton	1.899522	5	Cedar Bank
5	Cedar Bank	2.359966	6	Dunlap
6	Dunlap	4.790042	3	Blackwater
<b>Average</b>		4.804724		
<b>Standard Deviation</b>		2.973963		
<b>Median</b>		4.5694825		
<b>First Quartile</b>		2.38521925		
<b>Third Quartile</b>		6.42881975		

**Figure 34.** Results from Analysis IIB: Analysis of Spatiality – Manual Nearest Neighbor



**Figure 35.**

**Figure 35.** Histogram utilizing an equal interval classification scheme to display the distances to the nearest neighbor calculated in Analysis IIb: Analysis of Spatiality – Manual Nearest Neighbor.

**Figure 36.**

**Figure 36.** Histogram utilizing a standard deviation classification scheme to display the distances to the nearest neighbor calculated in Analysis IIb: Analysis of Spatiality – Manual Nearest Neighbor.

**Figure 37.**

Earthwork #	Earthwork Name	Distance to Nearest Neighbor (Kilometers)	Neighbor #	Neighbor Name
<b>Paint Creek Valley</b>				
18	Trefoil	5.767992	14	Seip
14	Seip	6.11452	2	Baum
2	Baum	2.552421	16	Spruce Hill
16	Spruce Hill	4.348923	4	Bourneville Circle
<b>Average</b>		4.695964		
<b>Standard Deviation</b>		1.620366		
<b>North Fork Valley</b>				
7	Frankfort	9.102358	10	Hopewell Mound Group
10	Hopewell Mound Group	2.838049	1	Anderson
1	Anderson	5.193377	17	Steele Group
17	Steele Group	1.652838	11	Junction Group
<b>Average</b>		4.696656		
<b>Standard Deviation</b>		3.285128		
<b>Scioto Valley</b>				
12	Liberty	5.677098	8	High Banks
8	High Banks	3.018426	19	Works East
19	Works East	8.166382	15	Shriver's Circle
15	Shriver's Circle	1.080208	13	Mound City
13	Mound City	2.393637	9	Hopeton
9	Hopeton	1.899522	5	Cedar Bank
5	Cedar Bank	2.359966	6	Dunlap
6	Dunlap	4.790042	3	Blackwater
<b>Average</b>		3.673160		
<b>Standard Deviation</b>		2.363767		

**Figure 37.** Results from Analysis IIB: Analysis of Spatiality – Manual Nearest Neighbor.

**Figure 38.**

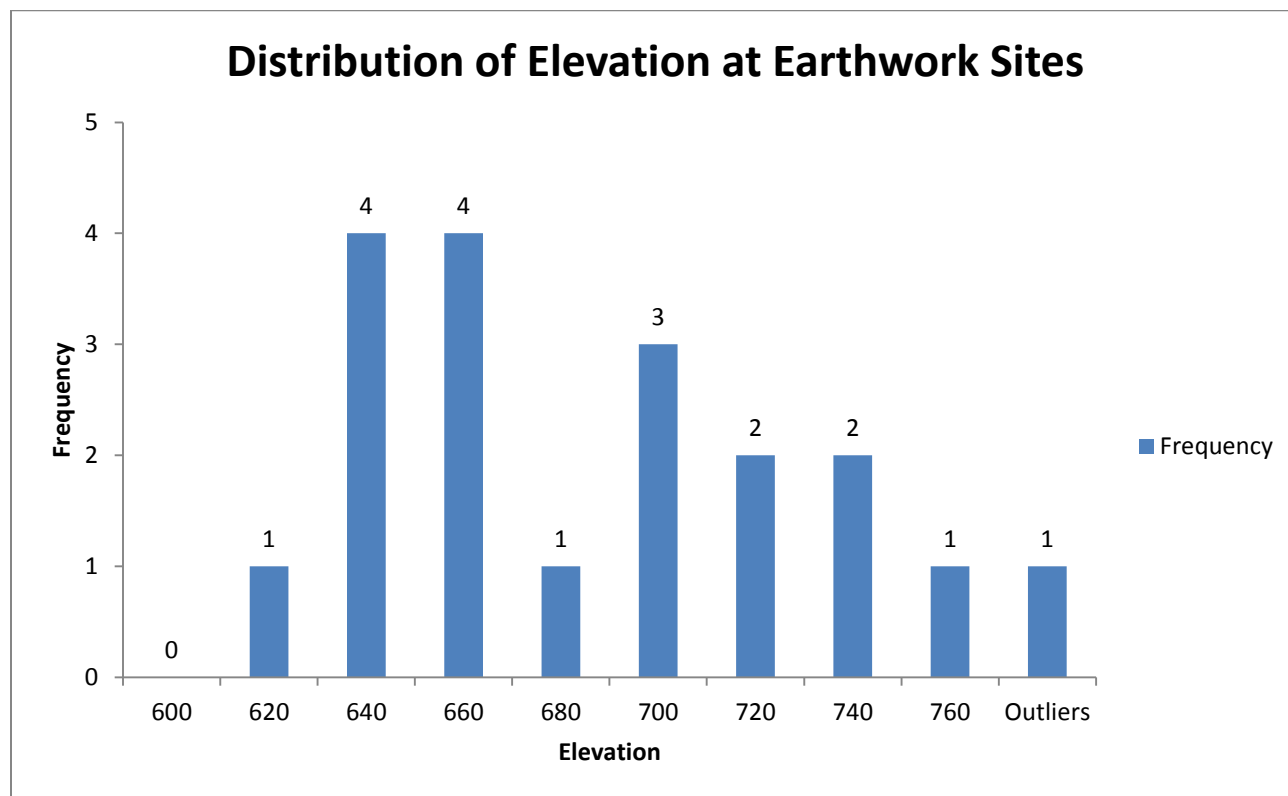
Earthwork Number	Earthwork Name	Elevation (feet)	Slope (Percentage)	Aspect	Bedrock Parent Material	Soil Type	Percentage of Ross County Soil
1	Anderson	698	0-6%	Flat (no aspect)	Wisconsinan Age Terrace	EeA: Eldean Loam	2%
2	Baum	688	0-2%	Northwest	Wisconsinan Age Terrace	EeA: Eldean Loam	2%
3	Blackwater	653	0-6%	Southwest	Wisconsinan Age Terrace	EeB/EeA: Eldean Loam	1.2/2%
4	Bourneville	725	0-2%	East	Wisconsinan Age Terrace	EeA: Eldean Loam	2%
5	Cedar Bank	696	2-6%	East	Wisconsinan Age Terrace	MhB: Miamian Silt Loam	2.40%
6	Dunlap	652	0-6%	Northeast	Wisconsinan Age Terrace	EeA: Eldean Loam/EgB: Eldean Gravelly Loam	2/0.4%
7	Frankfort	740	0-2%	East	Wisconsinan Age Terrace	EeA: Eldean Loam	2%
8	High Banks	637	0-6%	East	Wisconsinan Age Terrace	EeA: Eldean Loam/EgB: Eldean Gravelly Loam	2/0.4%
9	Hopeton	635	0-2%	West	Wisconsinan Age Terrace	MgA: Mentor Silt Loam, Gravelly Substratum	0.70%
10	Hopewell Mound Group	705	0-2%	South	Wisconsinan Age Terrace	EeA: Eldean Loam	2%
11	Junction Group	667	0-2%	Southeast	Wisconsinan Age Terrace	EeA: Eldean Loam	2%
12	Liberty	623	0-6%	Flat (no aspect)	Wisconsinan Age Terrace	EgB: Eldean Gravelly Loam/EeA: Eldean Loam	0.4%/2%
13	Mound City	648	0-2%	North	Wisconsinan Age Terrace	EgA: Eldean Gravelly Loam	0.20%
14	Seip	708	0-2%	Northeast	Wisconsinan Age Terrace	EeA: Eldean Loam	2%
15	Shriver's Circle	644	0-2%	West	Wisconsinan Age Terrace	EgA: Eldean Gravelly Loam	0.20%
16	Spruce Hill	1047	2-6%	Southeast	Wisconsinan Age Terrace	RpB: Rossmoyne Silt Loam	2%
17	Steele Group	639	0-2%	Southwest	Wisconsinan Age Terrace	EeA: Eldean Loam/EgA: Eldean Gravelly Loam	2%/0.2%
18	Trefoil	750	0-2%	Southwest	Wisconsinan Age Terrace	EeA: Eldean Loam	2%
19	Works East	604	0-2%	Southeast	Wisconsinan Age Terrace	Ge: Gessie Siltloam, occasionally flooded	4%

**Figure 38.** Results from Analysis III – Analysis of Environmental Factors.

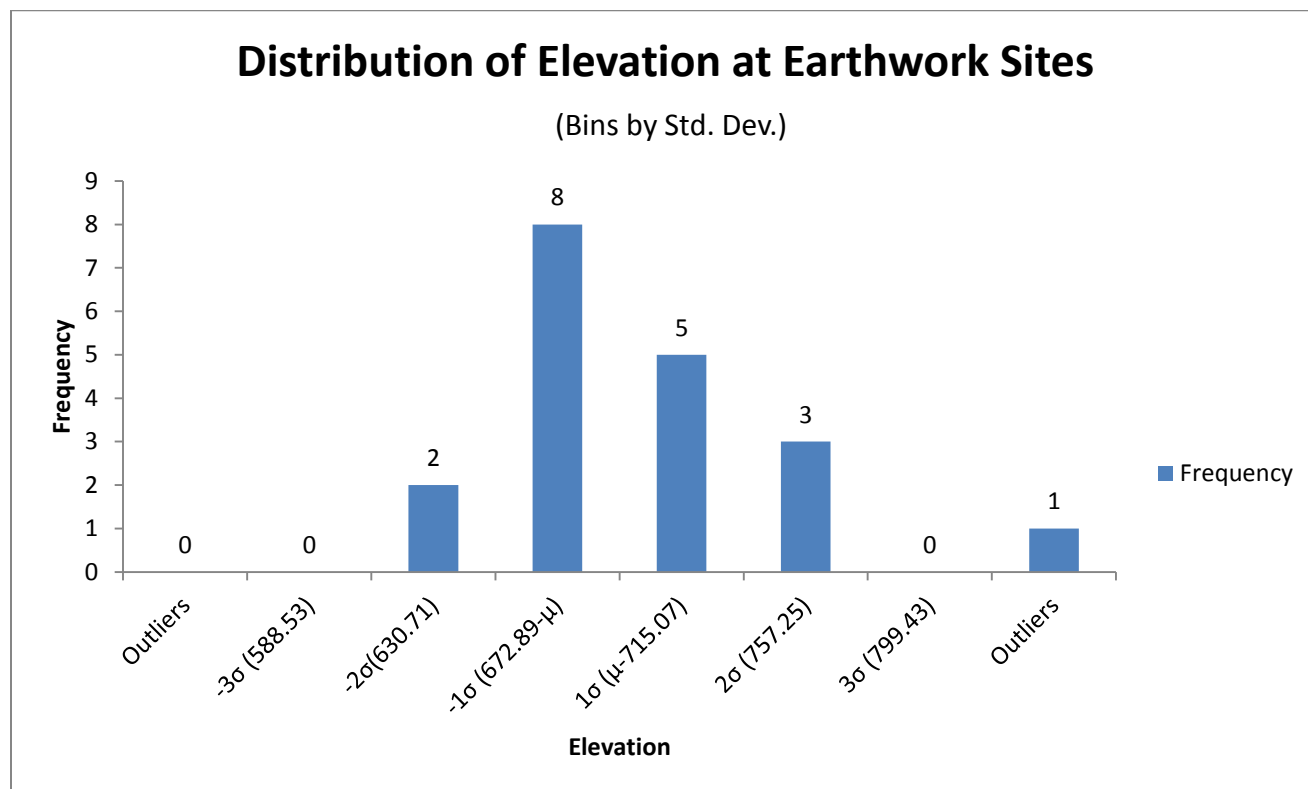
**Figure 39.**

<b>Earthwork Name</b>	<b>Elevation</b>
Anderson	698
Baum	688
Blackwater	653
Bourneville	725
Cedar Bank	696
Dunlap	652
Frankfort	740
High Banks	637
Hopeton	635
Hopewell Mound Group	705
Junction Group	667
Liberty	623
Mound City	648
Seip	708
Shriver's Circle	644
Spruce Hill	1047
Steele Group	639
Trefoil	750
Works East	604
<b>Average</b>	<b>692.58</b>
<b>Standard Deviation</b>	<b>95.11</b>
<b>Average w/o Outlier</b>	<b>672.89</b>
<b>Std. Dev. w/o Outlier</b>	<b>42.18</b>
<b>Median</b>	<b>667</b>
<b>First Quartile</b>	<b>639</b>
<b>Third Quartile</b>	<b>708</b>

**Figure 39.** Results from the portion Analysis III: Analysis of Environmental Factors considering elevation.

**Figure 40.**

**Figure 40.** Histogram utilizing an equal interval classification scheme to display the elevation at each earthwork site calculated in Analysis III: Analysis of Environmental Factors.

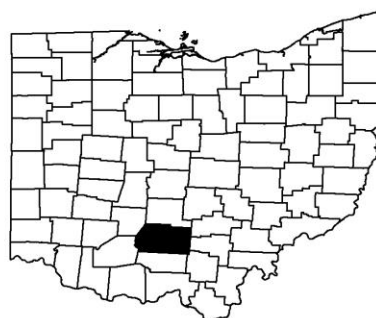
**Figure 41.**

**Figure 41.** Histogram utilizing a standard deviation classification scheme to display the elevation at each earthwork site calculated in Analysis III: Analysis of Environmental Factors.

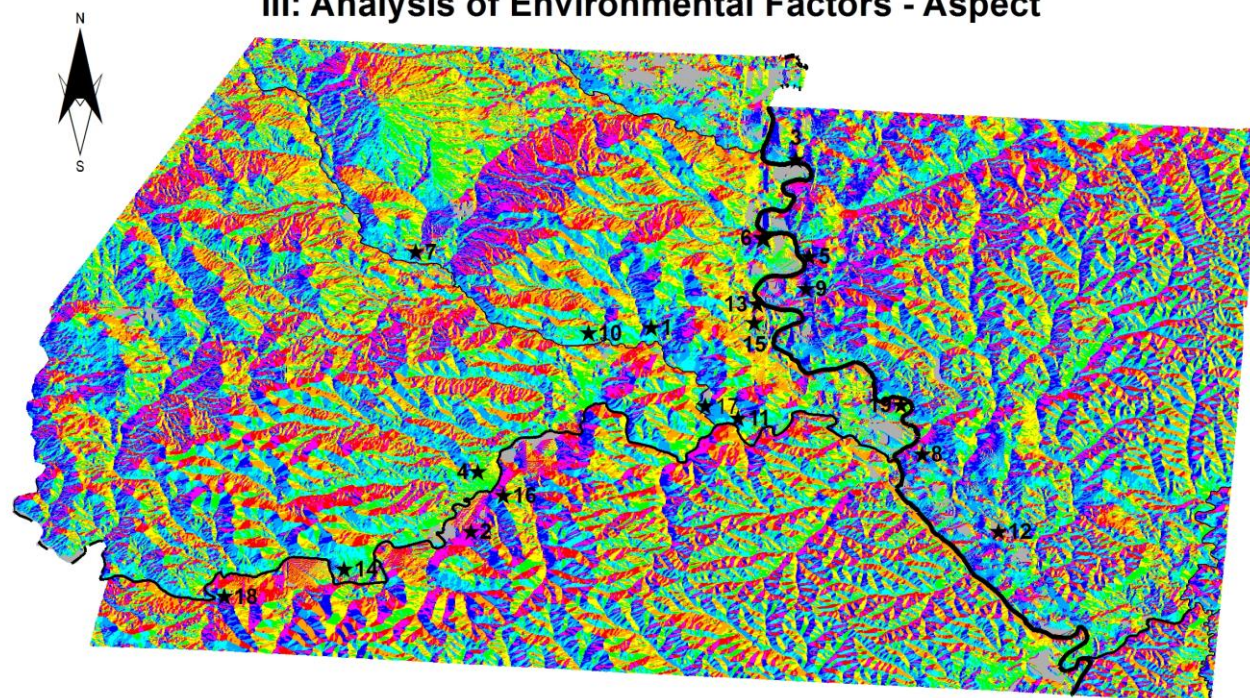
Figure 42.

## Investigating the Placement of Hopewell Earthworks: A GIS Spatial Analysis of Ross County, Ohio

Map Author: Timothy D. Everhart  
NAD 1983 UTM 17N  
21 March 2014



### III: Analysis of Environmental Factors - Aspect



#### Earthwork Name

- |                            |                        |
|----------------------------|------------------------|
| ★ 1. Anderson              | ★ 11. Junction Group   |
| ★ 2. Baum                  | ★ 12. Liberty          |
| ★ 3. Blackwater            | ★ 13. Mound City       |
| ★ 4. Bourneville Circle    | ★ 14. Seip             |
| ★ 5. Cedar Bank            | ★ 15. Shriver's Circle |
| ★ 6. Dunlap                | ★ 16. Spruce Hill      |
| ★ 7. Frankfort             | ★ 17. Steele Group     |
| ★ 8. Highbank              | ★ 18. Trefoil          |
| ★ 9. Hopeton               | ★ 19. Works East       |
| ★ 10. Hopewell Mound Group |                        |

0 5 10 20  
Kilometers

#### Data Sources:

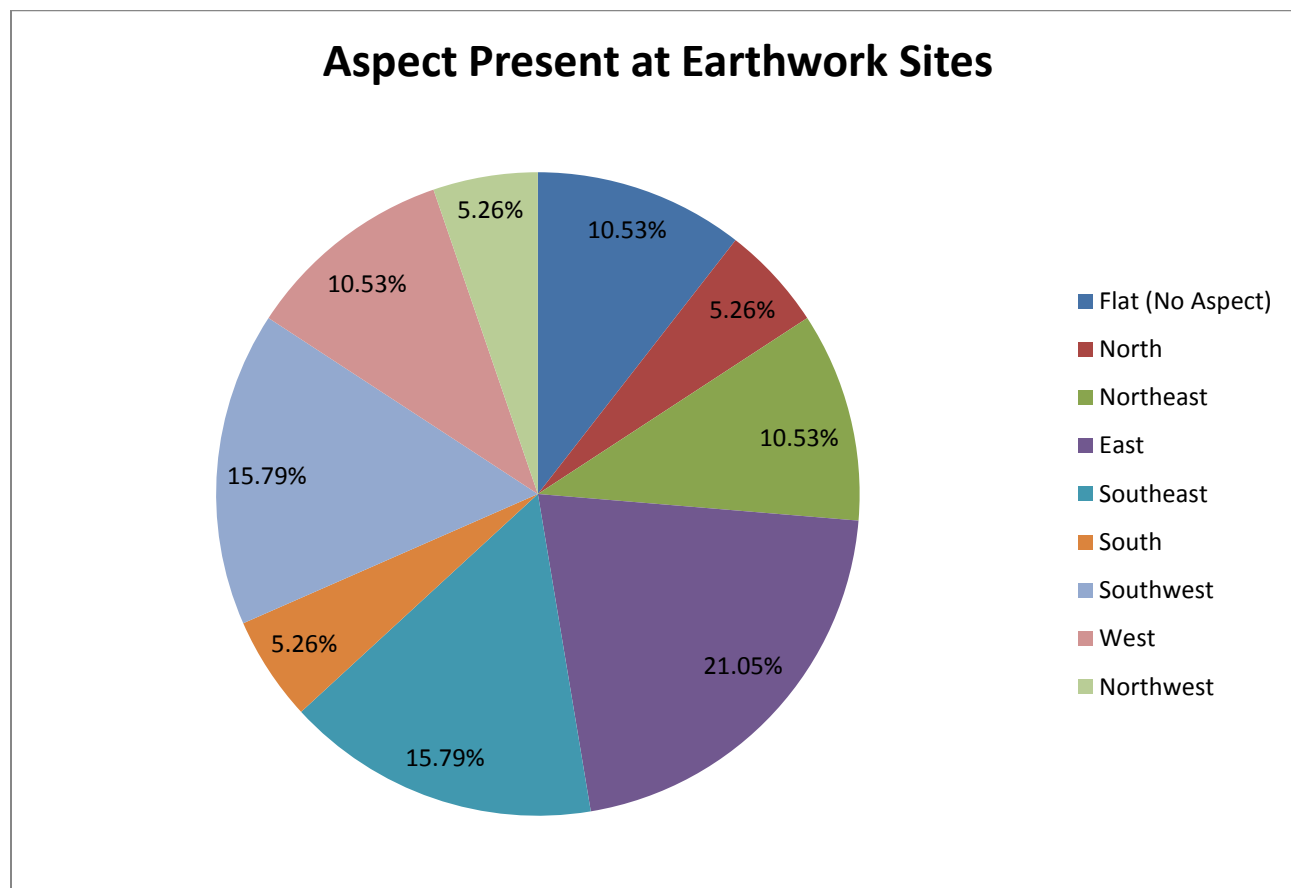
Case and Carr 2008  
USDA:NRCS  
Lute 2012  
NHDPlus



**Figure 43.**

Aspect	Percentage	Fraction
Flat (No Aspect)	10.53%	2/19
North	5.26%	1/19
Northeast	10.53%	2/19
East	21.05%	4/19
Southeast	15.79%	3/19
South	5.26%	1/19
Southwest	15.79%	3/19
West	10.53%	2/19
Northwest	5.26%	1/19

**Figure 43.** Results from the portion Analysis III: Analysis of Environmental Factors considering aspect.

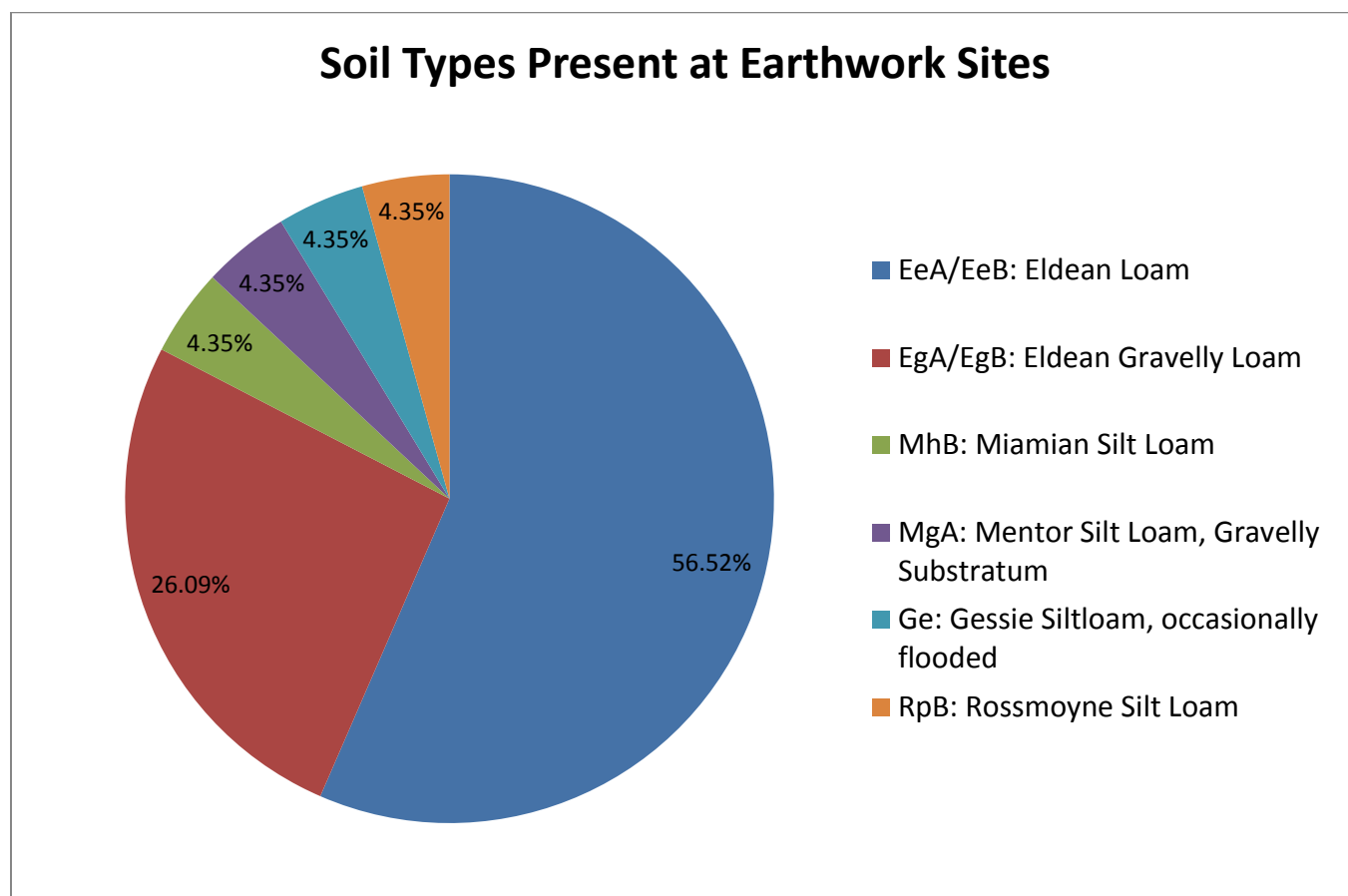
**Figure 44.**

**Figure 44.** Pie chart of the aspect present at each earthwork site calculated in Analysis III: Analysis of Environmental Factors.

**Figure 45.**

<b>Soil Type</b>	<b>Percentage</b>	<b>Fraction</b>
EeA/EeB: Eldean Loam	56.52%	13/23
EgA/EgB: Eldean Gravelly Loam	26.09%	6/23
MhB: Miamian Silt Loam	4.35%	1/23
MgA: Mentor Silt Loam, Gravelly Substratum	4.35%	1/23
Ge: Gessie Silt Loam, occasionally flooded	4.35%	1/23
RpB: Rossmoyne Silt Loam	4.35%	1/23

**Figure 45.** Results from the portion Analysis III: Analysis of Environmental Factors considering soil type.

**Figure 46.**

**Figure 46.** Pie chart of the soil type present at each earthwork site calculated in Analysis III: Analysis of Environmental Factors.

**Figure 47.**

	Elevation Range 1 (604-643)	Elevation Range 2 (654-702)	Elevation Range 3 (703-750)
Eldean Loam (EeA, EeB, EgA, EgB)	7	3	5
Other Soil Type (MgA, RpB, Ge, MhB)	2	1	1

**Figure 47.** Contingency table for the chi-square statistical test of elevation and soil type.

**Figure 48.**

	Range 1 Observed	Range 1 Expected	Range 2 Observed	Range 2 Expected	Range 3 Observed	Range 3 Expected	Total
Eldean Loam	7	7.11	3	3.16	5	4.74	15
Other Soil Type	2	1.89	1	0.84	1	1.26	4
Total	9		4		6		19

**Figure 48.** Table of expected and observed values for the chi-square statistical test of elevation and soil type.

**Figure 49.**

	O - E	$(O-E)^2$	$(O-E)^2/E$
Range 1, Eldean Loam	-0.11	0.0121	0.0017
Range 2, Eldean Loam	-0.16	0.0256	0.0081
Range 3, Eldean Loam	0.26	0.0676	0.0143
Range 1, Other Soil Type	0.11	0.0121	0.0064
Range 2, Other Soil Type	0.16	0.0256	0.0305
Range 3, Other Soil Type	-0.74	0.5476	0.4346
			Total = 0.4956

**Figure 49.** Table of contributions for the chi-square statistical test of elevation and soil type.



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